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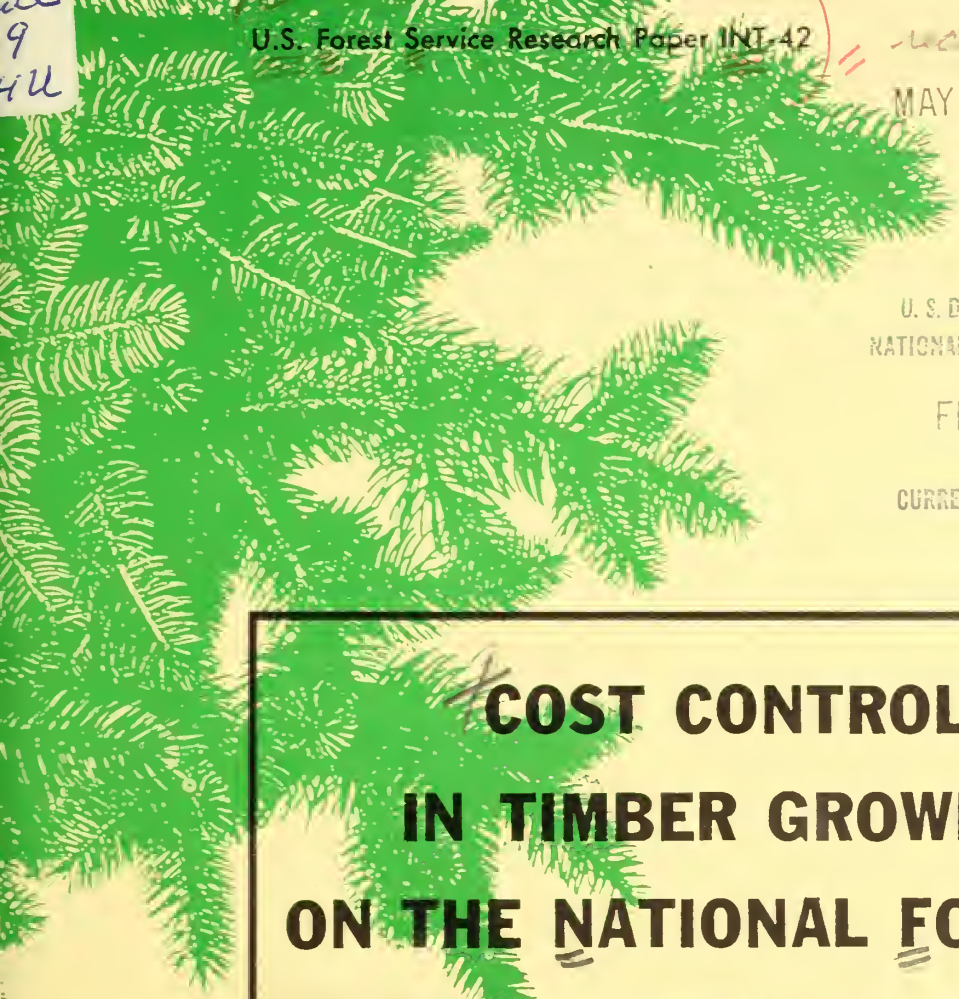

# COST CONTROL IN TIMBER GROWING ON THE NATIONAL FORESTS OF THE NORTHERN REGION

by

J. H. Wikstrom and J. R. Alley

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This is one of a series of reports published by the Intermountain Forest and Range Experiment Station. These reports are the result of a study initiated in 1962 to evaluate management alternatives on lands capable of growing white pine within National Forests in eastern Washington, northern Idaho, and western Montana. The work was done in cooperation with the Northern Region of the U.S. Forest Service. The following reports are included in the series:

*Relations between western white pine site index and tree height of several associated species*, by Glenn H. Deitschman and Alan W. Green. U.S. Forest Service Research Paper INT-22, 1965.

*Market trends for western white pine*, by Robert E. Benson and Larry L. Kirkwold. U.S. Forest Service Research Note INT-65, 1967.

*Evaluating species alternatives for National Forest land capable of growing western white pine*, by Alan W. Green and Jack R. Alley. U.S. Forest Service Research Paper INT-43.

*Ranking of treatment opportunities in existing timber stands on white pine land in the Northern Region*, by J. H. Wikstrom and Jack R. Alley. U.S. Forest Service Research Paper. (In preparation)

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# PREFACE

This paper discusses the efforts of the Northern Region and Intermountain Station to develop a more effective cost control system for timber management on the National Forest. It is primarily a description of what has been done thus far and should not be considered a final product, as work is continuing.

The details of cost effectiveness, methods of developing and keeping records, and handling of analysis no doubt could be approached in a number of ways, some of which might yield better results than those described here. However, it is not the purpose of this paper to argue details. This cooperative effort has demonstrated that there are opportunities for substantial cost savings in National Forest timber growing through a systematic approach to improved cost control, and this paper describes an approach that might be used.

# INTRODUCTION

In the absence of cost controls, any business involving a number of people and activities is subject to inefficiency. In a private organization this usually means failure; in a public operation it means waste of the taxpayers' money.

In a small business, private or public, cost control may be achieved by developing a few simple cost standards that make possible weighing of cost-value alternatives in work planning, and evaluation of cost effectiveness (the effectiveness with which money is utilized in carrying out a program). As a business grows in size and complexity, coordination is necessary to assure management follow-through, and cost control may require special accounting tools so that managers can keep informed of progress in every area of work. In large, highly complex businesses, cost effectiveness may depend on (1) the development of effective data collection and recordkeeping systems, (2) techniques to reduce and analyze large quantities of information, and (3) the quick communication of pertinent facts to decision makers.

The large-scale forestry enterprise of the Forest Service represents a most complex type of business from the standpoint of achieving cost control. Timber growing involves a number of interdependent actions. The degree of coordination achieved strongly influences both costs and results. A District Ranger may be simultaneously involved in timber harvesting, slash disposal, site preparation, regeneration, stand improvement, and protection on a large number of areas. These activities must be pursued in proper sequence and at the proper time.

Lack of uniformity adds greatly to the complexity of the forest operation. Rarely is an activity carried out on two areas under identical circumstances; consequently, the land manager must expect costs to change with conditions.

Considerable progress has been made in collecting information describing forest conditions. This progress is uneven, however. For some kinds of work, such as planting and thinning, most of the cost factors have been identified, although their influence has not been fully described and not all have been adequately measured. For other kinds of work, such as dozer piling and scarification, and prescribed burning, some cost factors are known but further studies must be made. For dozer piling and scarification, there is need to establish work quality standards and to conduct time and motion studies to identify factors influencing the cost of doing the job at the standard level. For prescribed burning, there is need for even more basic studies, aimed at identifying the cost factors in use of fire as a silvicultural tool.

Although much remains to be done, many of the factors that influence timber growing costs and results are now known, and it seems logical to begin updating management information systems to include data on these factors. Better information systems would allow managers to make more meaningful comparisons of costs and results of work.

Improvements in information systems in timber growing have greatly facilitated the study of costs. Better stand examination techniques have made possible more complete stand descriptions. With better data, work planning has been improved. Modifications have also been made in fiscal accounting so that individual project costs can be readily determined. With more complete information and electronic data processing, costs can now be quickly and easily matched to specific situations and the features of the job. Such tools as regression analysis[1] may now be used in attempts at determining which work situations are associated with high costs and which are associated with low costs. Thus, the key to cost analysis and cost control is good information systems. The purpose of part I of this discussion is to explain the Northern Region's timber management information systems. Part II illustrates cost analysis procedures and presents suggestions that should be helpful to foresters directly involved with cost analysis work.

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[1] *Regression analysis is a procedure for estimating or predicting unknown values of one variable (in this case costs of doing work) from known values of other variables (cost factors).*

# PART I

## INFORMATION SYSTEMS

The key to cost control in a complex business like timber growing is a combination of efficient management information systems. These systems must be capable of making pertinent data available to managers for use in making decisions. In timber growing this implies (1) a resource information system providing data on factors that affect cost or determine results of management actions, (2) a work planning information system that takes account of the job circumstances and identifies elements of the plan that influence cost and determine results, and (3) a cost information system that provides cost data that can be clearly related to both resource and job factors.

Such a combination of information systems is now possible in timber management planning, through the development of electronic data processing (EDP) equipment. Prior to this achievement, practical tools for dealing with the large number of cost factors and for analyzing the complex variations of the forest were not available. Timber managers, therefore, had only crude data to use in planning. In their operations generally, the sheer volume of information that had to be handled for program development, work coordination, and reporting of accomplishment was overwhelming, making cost analyses difficult and inaccurate. Today, EDP techniques capable of handling these complex problems have made possible a more sophisticated approach to timber management.

### Resource Information

#### Data collection

When facilities were available to handle large quantities of data, foresters were able to reconsider their data needs. In the years following World War II, the Forest Service adopted a two-stage approach to Forest Survey:[2]

*Stage 1.*—A survey of the forest as a whole to collect data for use in general forest planning and development of broad forest programs.

*Stage 2.*—A survey designed to collect data on individual stands for use in developing specific plans and programs.

In addition, timber survey procedures were revised to provide more definitive data describing the forest. The new procedure (used in both stage 1 and stage 2) attempts to describe the forest in terms of the physical and ecological factors that determine management of the land, including the kind, size, distribution, and condition of the trees or other ground cover present. Such data allow the timber manager to

1. determine the management treatment that would be beneficial to the forest,
2. estimate the capacity of the forest to respond to treatment, and
3. estimate the magnitude of the undertaking required by the treatment.

#### Data reduction and analysis

The information collected for each stand or area to be treated as a management unit can be reduced and summarized using EDP equipment. Summaries of stand area are put on a machine record (card or tape) for convenience in data storage and retrieval and ease of handling in development of a timber management program. A stand summary (see appendix A) describes each area physically and biologically and includes the basic resource information needed to determine appropriate treatment and the approximate cost of that treatment. The stand summary shows the age, number, and size of the potential crop trees.[3] It also specifies the amount of crown, the rate of growth, and the extent of disease or damage; these characteristics, along with site productivity, most strongly affect treatment response. In addition, for immature stands the summary shows the number and size of the trees that are in excess of stocking needs at that age. The number of excess trees, the size of the area, and its accessibility appear to be the principal factors affecting cost of controlling stocking. For nonstocked areas the information collected describes the land and cover.

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[2] *U.S. Forest Service, Intermountain Forest and Range Experiment Station, Divisions of Forest Economics Research and Forest Management Research. Developing the data framework for effective timber management. Misc. Pub. 25, 13 pp. 1962.*

[3] *Potential crop trees are those that would be featured were management of the stand to be intensified.*

### Work planning information

When the resource data base for timber management was improved, the door was opened to improved work planning. The work plan itself was improved by inclusion of measures of cost factors other than resources (accessibility, kind and amount of materials used, etc.). Also, more effective use of work plans in management control was made possible by improvement of fiscal data handling. For example, for effective control a manager must be able to compare planned and actual costs for his projects. That is, fiscal accounting must be related to work planning. In the EDP system this can be done through numerical coding. Also, since the condition of the stand or area treated not only influences the cost and determines the results of treatment, but is itself changed as a result of treatment, there must be a tie-in between reporting of work plan accomplishment and resource accounting. Such a tie-in is provided for in the information system, allowing resource records to be kept current.

In the Northern Region of the Forest Service, work plans are incorporated into the management information systems. Each approved uniform work plan is given an identifying number and made a part of the computer record, so that work progress records can be kept up to date by machine accounting. The information contained in the records can be quickly and easily reached when needed. For example, to facilitate scheduled reviews of the work program, periodically a machine summary may be prepared of the planned work of each Forest and District, showing the status of each project (that is, approved or completed) and the accrued costs in relation to the planned expenditures. An example of this summary is given in appendix B.

### Fiscal information

The Forest Service historically has used a fund account system; the dollars appropriated by Congress for different uses are allocated to the Forests, and as work is done, charges are made against the appropriate fund. The system in itself does not provide for accounting by individual project or for identifying costs that can be related to work accomplishments or work situations. Thus it does not provide the cost information needed by managers for work planning, supervision, and progress evaluation. However, the fiscal accounting system can be easily modified to provide such information. In the process, cost data can be made available for analysis aimed at identifying cost factors and describing their influence.

### Identifying costs

Three categories of costs are recognized in timber growing. First, there are direct project costs that can be assigned to a single project as they are incurred. Second, there are charges that are also direct project costs but that must be shared with certain other projects. (Included in this class are such items as chainsaws that are amortized on a number of projects, or the cost of constructing and operating a camp that serves a number of projects. Also included are the wages of personnel assigned to project planning and administration and paid directly out of project funds that cannot conveniently be broken down according to individual projects.) Third, there are overhead charges at the Ranger District, Supervisor's Office, Regional Office, and Washington Office levels.

In Forest Service accounting, managerial accounts (general overhead) are identified. To classify costs, therefore, it is necessary only to identify a charge as falling within one of the two remaining major categories (those directly chargeable to specific projects or those that must be prorated among projects). Because a breakdown of costs by project is needed for work planning and evaluation, the logical place to begin cost control is with charges that can be assigned directly to projects — those charges influenced directly by project circumstances.

### Modifying the accounting system

The practical way to collect cost information needed for work planning, evaluation, and control is through the accounting system. If project costs are identified and adequately described on the basic expense documents, the problem is virtually solved. Data reduction and analysis can then be conveniently handled by machine.

The accounting system used by the Forest Service is sufficiently flexible to permit identifying projects and describing costs in detail. For instance, since Forests and Ranger Districts are already identified on expense documents, in order to relate the cost to the project it is necessary only to add a number identifying the project. If the uniform work plan number is used as a project number, costs can be machine matched with the work plan and resource record and related to specific situations and job features (see appendix B).

## FACTORS AFFECTING COSTS OF TIMBER GROWING

As mentioned earlier, knowledge of cost factors for certain kinds of work is limited. Studies of such work are needed so that the information systems can be completed. Also, improvements are needed in uniform work planning to assure that the job being done is adequately measured in all cases.

The incompleteness of the information systems indicates an important area where additional work is needed. However, the task of completing the information and the task of analyzing costs must be considered jointly. A major reason for adding or deleting items in the information systems is that the data gathered do not adequately measure the job or reflect the cost. Either important factors affecting cost are being overlooked, or data are included that are extraneous to planning and cost control or other needs.

As stated earlier, many factors influencing project level costs[1] have been identified and their influence has been at least partially evaluated so that managers can begin using this information. A selection of such factors is shown in table 1; their influence is summarized in a general way, through a ranking system based on the authors' experience and judgment.

### Key factors of cost

Only a few of the many activities of timber management are shown in table 1. It is evident, however, that some of the cost factors in these activities are especially influential. Size of area, accessibility, and certain factors that measure the job to be done are key factors of cost.

### Size of area

The size of the area treated is perhaps the determining factor in the cost of most timber growing projects. However, we must recognize that project cost may not increase in direct proportion to increase in size of area. In other words, cost relationships change with size of area and type of work performed. For most kinds of timber growing jobs, cost per acre increases rapidly with decreases in size of area, particularly for areas smaller than 40 to 50 acres. Figure 1 shows this relationship for planting, prescribed burning, and dozer terracing. The curves shown in the figure were computed holding all other variables at their mean levels.

### Accessibility

Accessibility is also a very important element in timber growing costs in the Northern Region. As a measurement, accessibility is principally expressed in transportation time and expense. Transportation cost in the form of equipment mileage usually is not a particularly large item. Although it may run as high as $6 an acre for small areas located a long distance from a work center, the average is only about $1.25 an acre. However, travel

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[1] *Cost analyses made thus far have been limited to the project level. No attempt has been made as a part of this study to analyze Ranger District, Supervisor's Office, or Regional Office overhead costs.*

Table 1.—**Some factors that influence costs of timber management activities, rated according to degree of influence**[1]

| Factors affecting cost | Site preparation | | | | | Thinning | | |
|---|---|---|---|---|---|---|---|---|
| | Slashing | Prescribed burning | Dozer piling | Dozer terracing | Planting | Marking | Cutting | Pruning |
| Size of area | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| Accessibility | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Volume of material handled: | | | | | | | | |
| Number of trees | 2 | -- | -- | -- | 2 | 2 | 2 | 2 |
| Size of trees | 2 | -- | -- | -- | -- | 1 | 2 | 1 |
| Residual volume | -- | 1 | 3 | 3 | -- | -- | -- | -- |
| Soil | -- | -- | 1 | 1 | 1 | -- | -- | -- |
| Slope | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 |
| Aspect | -- | 2 | 1 | -- | -- | -- | -- | -- |
| Brush cover | -- | -- | -- | 1 | 1 | 1 | 1 | 1 |
| Down material | 1 | -- | -- | 1 | 2 | 1 | 1 | 1 |
| Weather | -- | 2 | -- | 1 | -- | 1 | 1 | 1 |
| Finance class[2] | 1 | -- | 1 | 1 | 1 | -- | 1 | -- |

[1] -- denotes insignificant or not applicable; 1, moderate; 2, major; 3, critical.

[2] Work done by organization employees (force account) as opposed to contract work.

time can cut deeply into the working day of the crew. In hand planting, for example, even on the average planting project, crews are working on the project site planting trees only about 6 hours a day.

### Factors that measure the job

In addition to size of area and accessibility, the most critical factors affecting cost are those that measure the amount of work done; that is, the number of trees planted, the number and size of trees felled, pruned, or treated, or the volume of material handled.

At the present time, data describing the unit volume of work done are lacking for some types of work, and for others data are often weak. However, where data are available, there appears to be a consistent relationship between the factors that measure the volume of work and the per-acre cost of the job. In hand planting of trees, assuming other variables are held at mean levels, a decision to increase planting density 100 trees per acre is apparently a decision to add $4.90 to the per-acre planting cost, excluding the cost of the trees (fig. 2).

### Other factors of cost

A number of other factors can have a significant effect on the cost of different kinds of jobs: for example, kind and depth of soil and amount of brush cover and down material on a planting site, slope on a thinning or slashing project, fuel condition on a burning project, and weather on all projects. In addition, the general nature of the job may be a cost factor. For example, it is often found that some types of work can be accomplished as well or better and at less cost by contract crews than by employed personnel.

Also, in many instances timing of work, quality of planning, and coordination have proved to be extremely important considerations, even though these conditions cannot be predicted. A thinning project attempted in midwinter under adverse conditions, for example, cost 700 percent more than a comparable project completed under favorable conditions. Again, a prescribed burn on an area poorly designed and laid out cost over 1,000 percent more than the average cost for all the year's burning projects. Examples of high costs due to poor coordination are

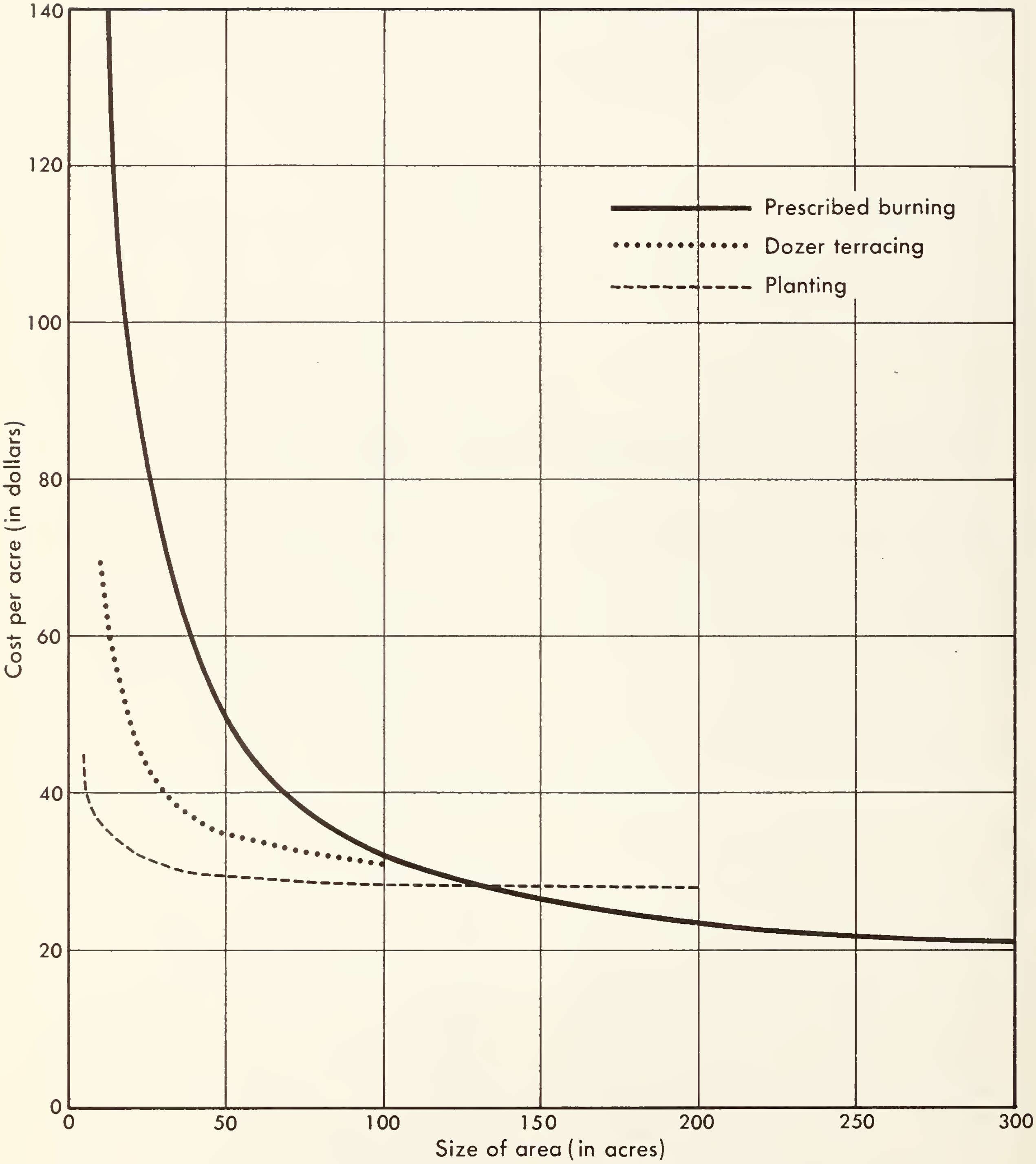

Figure 1. — Relationship of cost per acre to size of area in selected jobs. (In computation of data points, other variables were held at their mean levels.)

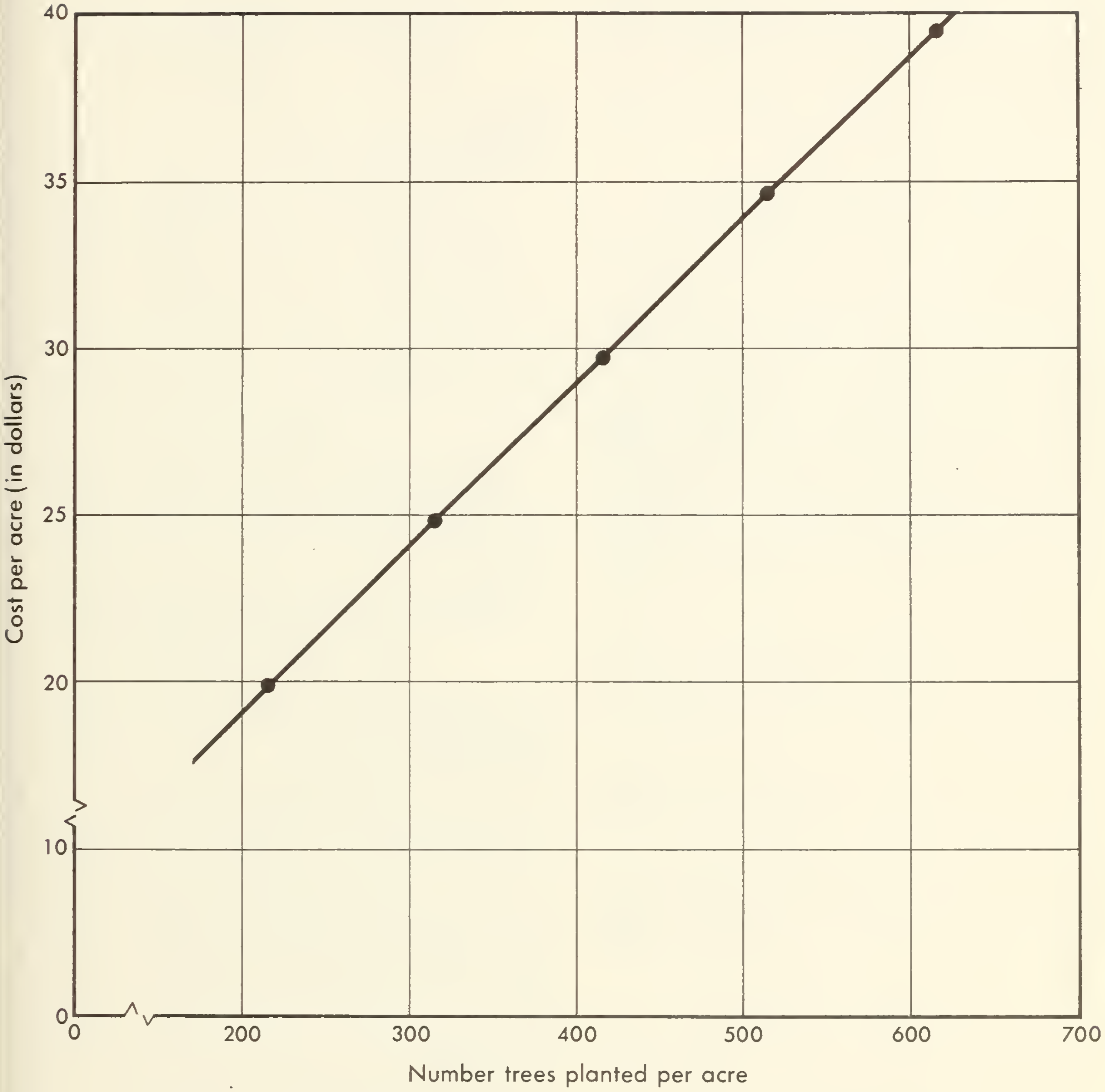

Figure 2. — Relationship of cost per acre to number of trees planted per acre, in hand planting. (In computation of data points, other variables were held at their mean levels.)

common. Delays in prescribed burning often result in loss of fine fuels, so that ignition is more difficult. Delays in planting allow brush and sod to become established on the site, making the planting more difficult. After the second season following site preparation, further delays in planting result in an increased cost of about $1 per hundred trees planted, for each year of delay.

### Some cost prediction equations

When the factors that influence cost have been identified, the regression analysis may be run with the aid of the computer. Following are some examples of project cost[5] prediction equations with related statistics, for selected types of work. These equations are not proposed for others to use. Like all equations developed by regression analysis, they are usable only in the areas where the samples were taken and within the range of variation sampled. The method by which these equations were developed will be illustrated in part II.[6]

### Hand planting

Project cost in dollars = 211.44 + 0.108 (area$^2$) + 0.027 (total number of trees planted).

Adjustments to be made according to class of down material for the average project (58.3 acres):

Heavy down material, add $140.69
Medium down material, no change
Light down material, subtract $140.69

$R^2 = 0.979$
Mean cost = $1,589.36
Standard error = 281.95

### Dozer piling and scarification

Project cost = 175.94 + 34.99 (area) + 0.0002 (estimated vehicle mileage × area$^2$).

$R^2 = 0.870$
Mean cost = $1,538.85
Standard error = 785.415

### Thinning

Project cost = 203.73 + 13.37 (area) + 0.56 (estimated vehicle mileage) + 0.033 (number of trees to be cut per acre × average tree size$^2$).

Adjustment to be made for finance class on the average project (51.9 acres):

Force account, add $277.48
Contract, subtract $277.48

$R^2 = 0.84$
Mean cost = $1,455.79
Standard error = 582.69

Note that the $R^2$ for these equations is lower for dozer piling and scarification and for thinning than it is for hand planting. The lower $R^2$ values suggest a probable need for more work on data development in these two areas, as indicated in the earlier discussion.

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[5] *Project level costs do not include Ranger District, Supervisor's Office, Regional Office, or Washington Office overhead.*

[6] *Note: Project cost is cost less planting stock. Values in the equation are constants or coefficients to be multiplied by the appropriate values for the items in parentheses. The $R^2$ indicates the amount of variation in project cost (dependent variable) explained by the independent variables in the equation.*

# PART II

## COST ANALYSIS IN TIMBER GROWING

A broad goal of timber managers is the ability to accurately relate costs to yields. Cost comparisons in timber growing are difficult to evaluate; a thinning cost of $8 an acre may be high in one case, and a cost of $40 an acre may be low in another, depending on the situations and the results achieved.

The immediate problem of most timber managers, however, and the one we are concerned with here, is to make realistic advance estimates of costs for different jobs under any given set of circumstances. Such estimates are essential in work planning, budgeting of funds, and evaluation of work accomplishments. The method that will be described in the following pages is the development of cost prediction equations based on sample data (from past experience) which are analyzed with the help of the computer, using standard statistical techniques.

The method does not guarantee accuracy, because in timber growing unpredictable factors such as weather can often strongly influence project costs. Nevertheless, it is possible to explain a large part of the variation in costs as due to measurable factors, and thus to make estimates that are helpful in practical timber management.

It is important to recognize that the cost prediction equation derived from any given set of data is not a final answer to the problem of cost estimate. The equation continually needs updating as new cost information becomes available or advances are achieved in technology. Also, it would be unusual if a completely usable cost prediction equation could be developed from one set of data. In most instances the data being analyzed at any one time are not designed to measure all factors. Certain factors that are present in a particular data set may be overlooked in the analysis simply because in the situations measured they did not vary. However, even though the analyst suffers under these limitations, with the computers now available he has the ability to analyze efficiently both large volumes of data and numerous sets of data.

### Developing the cost prediction equation

The cost prediction equation is an expression of the relationship of the cost of doing work to the variables that influence the cost. Developing such an equation is sometimes referred to as model building; however, the approach proposed here is not model building in the strict conceptual sense. Rather, it is a process of regression analysis, through which polynomial forms are found to express the relationships between costs and individual variables. As Draper and Smith[7] point out, it has been shown that polynomial forms can be used to approximate true relationships over limited ranges. Study of these approximations casts light on the underlying complex relationships.

Regression analysis involves the selection and testing of independent variables in a given situation to determine their effect, individually and in combination, on a dependent variable. The basic multiple linear equation is as follows:

$$Y_o = B_o + \sum_{i=1}^{i=n} B_i X_i$$

where

$Y_o$ = the dependent variable (here, cost)
$B_o$ = the regression constant
$n$ = the number of independent variables
$B_i$ = the standardized regression coefficient for the $i^{th}$ (indicated) independent variable
$X_i$ = the value of the $i^{th}$ independent variable indicated, $i = 1, \ldots n$.

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[7] *Draper, N. R., and H. Smith, Applied regression analysis. 407 pp. N.Y.: John Wiley and Sons. 1967. Also see Ezekiel, Mordecai, and Karl A. Fox. Methods of correlation and regression analysis. 3rd Ed. 548 pp. N.Y.: John Wiley and Sons. 1959.*

The solution of this equation, on the basis of the sets of data gathered in completed projects, can be largely accomplished by the computer, which may be programmed to test concurrently various combinations of independent variables ($X_i$'s). It is the task of the analyst to study the data in order to select the pertinent factors to be tested, and to study the computer output so as to select the combination of factors that best explains the variation in costs. These procedures will be explained more fully in succeeding sections of this paper.

## Preliminary study of data

The first task in developing the cost prediction equation is to study the data and select from all the factors measured those which seem pertinent to the particular job to be estimated. It is also necessary to decide how these factors are best handled in the estimate.

### Handling of specific costs

The analyst will have to decide which specific costs should be included in the cost equation itself and which are best handled outside the main regression equation. Costs that can be determined without error are best treated as an additive part of the equation. In tree planting the cost of planting stock is normally handled as an addition to the base estimate, because once the kind and number of trees to be planted have been specified, the stock cost can be determined from the nursery price list.

Sometimes it is desirable to isolate certain costs for separate analysis because they are not influenced by the same factors that influence the cost of the rest of the job. A case in point is the transportation cost associated with many timber growing jobs. A separate analysis is usually appropriate, because the amount of transportation is dependent on trips required, road characteristics, and the distance between the job site and the employment base. However, transportation may also be considered a variable of cost, since crew travel on official time affects the on-site cost of doing a job.

In some instances it may be desirable to distinguish a specific situation and develop a separate prediction equation for it. Where jobs may be either contracted for or performed by organization staff, it may be desirable to develop one equation for estimating what contractors might bid, and another equation for estimating the cost of work done by staff members (force account).

The experienced manager, with the aid of the data, will usually be able to decide how the analysis might best be structured. Beyond this the principles involved are the same.

### Discrete variables

Some of the factors selected as pertinent to the analysis may be "class" or "discrete" variables—factors that are not inherently quantified. These may include such variables as managerial units (Forests or Districts), or species types, or adjective classifications of financing procedure, site condition, or season of year. These variables must be handled by special analysis techniques, primarily coding. That is, the discrete variables may be labeled in the data set with numbers (codes) that are for identification only and do not reflect the capacity of the variables to influence the dependent variable. (The numbers used to identify species type, for example, 017 for grand fir and 093 for Engelmann spruce, in no way reflect the cost advantage or disadvantage of operating in one type over the other.) Such identification codes are rarely usable in comparing classes. If it is necessary to compare and evaluate class influences on the dependent variable and to develop analytical values that can be used in regression, "dummy" variables are set up. Arbitrary values are assigned to represent the probable range of variation in the discrete variable, and these values are used in place of the identification codes. The procedure for assigning values and developing regression coefficients is illustrated in examples presented later in the text. (For a detailed explanation that includes problems involving complicated comparisons, see Draper and Smith.[8])

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[8] *See footnote 7.*

### Nondiscrete variables — curve fitting

Before the data for the cost prediction equation itself can be fed into the computer, the data for the selected factors must be studied in some detail to determine the nature of the relationships that exist between the cost factors and the cost of doing work. The main problem is to determine whether the relationships are linear or not. In doing this, the analyst may encounter difficulties requiring the help of a statistician, but in general he can follow a simple plan. That is, the values for the dependent variable $Y$ must be plotted over the corresponding values of the independent variable $X_i$. If the plotted points do not form a pattern that may be approximated by a straight line (expressed by the polynomial $Y = a + bX$, it is necessary to find the proper expression for the curve that will fit the data.[9] For example, the curve may be found to approximate one expressed by the equation $Y = a + b(X^2)$, or possibly $X^3$, log $X$, or $1/X$. Whatever function of the variable ($X$) is decided upon is then incorporated in the machine program for the cost prediction equation, and data that are transformed accordingly are fed into the computer. (The fit of the curve is tested mathematically for accuracy, as will be explained in a later section.)

### Nondiscrete variables — products of variables

It may be desirable to use the products of different variables, as when interactions are involved and when it is necessary to develop joint functions for two or more independent variables. For example, if changes in cost in relation to size of area are dependent at least in part on planting density, it might be advantageous to express the cost change as a function of area and planting density combined.

## Illustration of equation development

Data collected on hand planting costs for the 1965 fall planting season will be used here to illustrate the development of a cost equation. The costs of these planting projects (less planting stock) were first listed by Ranger Districts and Forests to allow a check for any extremely high or low cost that could be due to accounting errors or abnormal circumstances. In addition, average per-acre costs, average project size (size of area planted), and average planting density (number of trees planted per acre) were computed for each Ranger District or Forest to check for differences between management units. Any such differences that were discovered appeared to be due largely to differences in planting density and species planted. Costs were higher for units that had planted white pine. White pine is more difficult to plant because planting is not done until 2 to 4 years after site preparation, and planting crews have to contend with much grass and brush. A summary of projects by species planted showed the difference in average planting cost to be as follows:

| *Species planted* | *Average cost per acre* |
|---|---|
| White pine | $35.12 |
| Other | 25.52 |

The projects were also summarized according to finance class (contract or force account), amount of brush cover, amount of down material, size class in terms of area, and size class in terms of total number of trees planted.

The summary by finance class indicated that contract planting cost more than force account planting;[10] however, all the white pine planting was done by contractors. Part of the higher cost of contract planting can probably be attributed to this fact, and the remainder is at least partially explained by a difference in the number of trees planted.

| *Finance class* | *Average cost per acre* | *Avg. no. of trees per acre* |
|---|---|---|
| Contract planting | $29.72 | 437 |
| Force account planting | 24.71 | 389 |

---

[9] *Curve fitting is described in detail by Ezekiel and Fox (see footnote 7). See also Jensen, Chester E. Algebraic descriptions of forms in space. 57 pp. U.S. Dep. Agr., Forest Serv., Central States Forest Exp. Sta., Columbus, Ohio. 1964.*

[10] *This does not mean total cost of contract planting exceeds the cost of force account planting. Overhead cost associated with contract work is usually lower than for force account work.*

If both contractors and Forest Service crews had been planting 400 trees per acre, the difference in per-acre cost of planting would have been only $1.60.

There was also an apparent difference in cost due to the amount of brush cover and down material. Projects with brush cover, down material, or both that were classed as heavy cost a little more than projects on which these elements were classed as light. However, these subjective classifications will not stand close analysis. As yet no objective measure of brush cover and down material has been used.

The data for the nondiscrete variables were plotted so that curves could be fitted that described the relationship of the dependent variable to each independent variable. For example, project cost (less stock cost) was plotted over project area (fig. 3). (Project cost was also plotted over total trees planted. This relationship appeared to be linear.)

It was obvious from the general pattern of the data points that there was a relatively high correlation between project cost and size of area. However, the important thing here is not so much the fact of apparent correlation as the exact nature of the relationship between the dependent variable and the independent variable. In other words, what is the shape of the curve that could be fitted to the data so that the deviation of the points from the line would be independent of any of the cost factors, singly or in combination?

As shown in figure 3, the deviations are not independent of area when a straight line is used to describe the relationship between project cost and size of area. Such a line, passing through the mean in this case, leaves most of the points at the ends of the line falling above the line, while in the middle the majority of the points fall below the line.

The relationship of project cost to size of area is thus curvilinear, and a function of one or both variables that fits the data must be found. In this instance, the data were first plotted on semilog paper with log $Y$ as the dependent variable. However, even when plotted on semilog paper, the relationship could not be adequately described with a straight line; this fact suggested that a different function was needed.

A curve of the form $Y=a+b(X^2)$ was then tried, and as indicated in figure 3, this curve appeared to describe the relationship quite well. (The form of the curve indicates that the data are independent and would plot as a straight line against area$^2$.)

The fit of the line should be tested mathematically as well as visually. This can be done by comparing the variance in the original $Y$'s (cost) with the variance in the $Y$'s estimated from the curve.

Variance of the original $Y$'s is usually identified by the symbol $S^2_y$. The variance of the $Y$'s after the curve is fitted is usually identified as $S^2_y \,.\, x_1x_2 \ldots x_m$. The curve of best fit would be the one that resulted in the highest ratio of

$$\frac{S^2_y}{S^2_y \,.\, x_1x_2 \ldots x_m}$$

There is a difficulty involved in this method, however, in that it assumes the estimated $Y$'s to be in the same units as the original $Y$'s. This is not so; a coefficient of correlation ($r$) of $Y$ on $X$ cannot be compared directly with a coefficient of correlation of log $Y$ on $X$. The estimates of log $Y$ must be transformed back to $Y'$ so the variance in $Y'$ can be determined. In other words, the $r$ values[11] developed by the regression program cannot be used without detransformation to compare how well the two functions fit the data.

For the three curve forms tried out to explain the relationship of project cost to size of area, the $r$ values were as follows:

| | | |
|---|---|---|
| $Y=a+bX$ | 0.948 | |
| Log $Y=a+bX$ | .951 | ($r$ value after the data were detransformed) |
| $Y=a+b(X^2)$ | .968 | |

In addition to those described above, curves were fitted for cost per acre plotted over size

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[11] *The range of the correlation index* r, *ignoring the sign, is from 0.0 to 1.0. This index measures the correlation of* Y *on* X; *that is, it tells how well the line or curve fits the data. It is not to be confused with the multiple correlation index* (R), *which expresses the correlation of a number of variables combined, or the coefficient of determination, often called* R$^2$, *which measures the variation accounted for by the variables and their functions in a particular regression equation.*

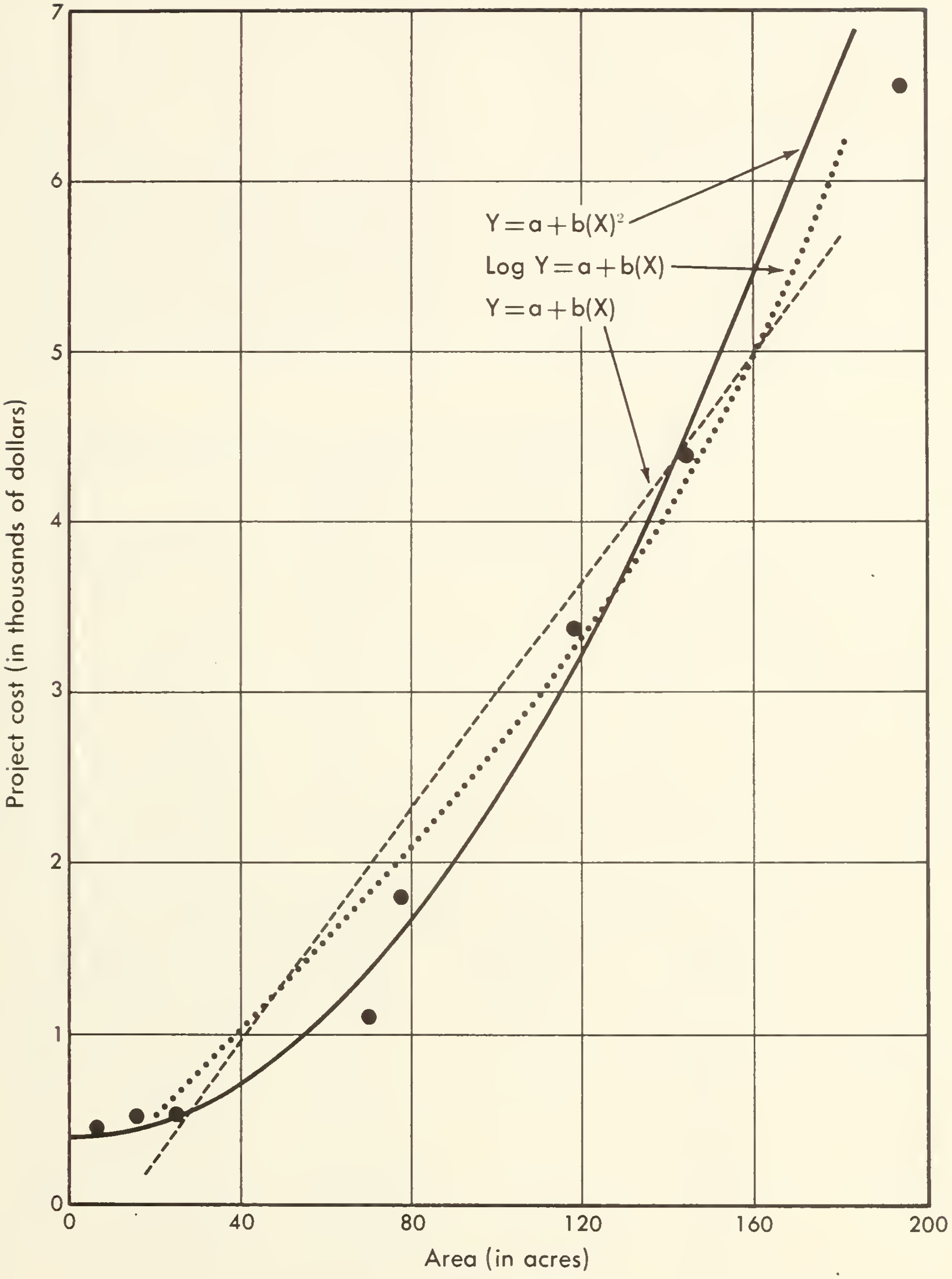

Figure 3. — A test of three polynomials to explain the relationship of project cost to project size. Projects were grouped into size classes and the average cost for each class was plotted over the average project size for the class.

of area, over number of trees planted per acre, and over slope percent of the land. With the exception of the one for slope percent, these graphs showed some interesting relationships. First of all, aside from the influence of a large high-cost contract project where white pine was planted, there was a definite straight-line relationship between cost per acre and number of trees planted (see data in table 2). This relationship was illustrated in figure 2. More complicated was the way cost per acre changed with size of area. When the projects were grouped into size classes and the data were plotted, cost was shown to decrease rapidly as project size increased, up to a point where the curve leveled off; it later began to turn up again (fig. 4).

The fact that costs per acre began to increase again for the larger projects could, however, be explained: (1) part of the tendency was due to increases in planting density in the large projects (table 3); (2) most of the large projects were contracted and the number of contractors who can handle such projects is limited, so contract planters apparently increase their bids on them; and (3) as mentioned above, two large projects were white pine, which is the most expen-

Table 2. — **Summary of 1965 fall planting costs by planting density classes**

| Planting density class | Number of trees | Average for class | Number of projects | Average project size | Cost Per acre | Cost Per tree |
|---|---|---|---|---|---|---|
| | | | | *Acres* | *Dollars* | *Dollars* |
| 1 | 1-200 | 150 | 5 | 35.4 | 12.46 | 0.083 |
| 2 | 201-300 | 265 | 6 | 28.0 | 15.28 | .058 |
| 3 | 301-400 | 339 | 11 | 97.5 | 28.86<br>[1]21.70 | .085<br>[1].064 |
| 4 | 401-500 | 458 | 13 | 56.5 | 25.93 | .057 |
| 5 | 500+ | 540 | 18 | 52.1 | 30.38 | .056 |
| All projects | | 413 | 53 | 58.3 | 26.95 | .065 |

[1] Data adjusted to take out species and contractor influence.

Table 3. — **Summary of 1965 fall hand-planting projects**

| Size class | Average area | Number of projects | Number of trees/acre | Cost Per acre | Cost Per tree |
|---|---|---|---|---|---|
| | *Acres* | | | *Dollars* | *Dollars* |
| 1-10 | 5.0 | 4 | 520 | 82.60 | 0.16 |
| 11-20 | 14.1 | 8 | 442 | 31.80 | .07 |
| 21-30 | 25.6 | 9 | 299 | 21.18 | .07 |
| 31-40 | 34.0 | 7 | 359 | 17.36 | .05 |
| 41-60 | 50.3 | 6 | 437 | 25.02 | .06 |
| 61-100 | 78.9 | 10 | 462 | 24.08 | .05 |
| 100-150 | 119.0 | 5 | 455 | 28.04<br>[1]20.24 | .06 |
| 150+ | 200.5 | 4 | 368 | 33.36<br>[1]19.94 | .09 |
| All projects | 58.3 | 53 | 413 | 27.27 | .07 |

[1] Adjusted to average planting density and for differences due to species and the influence of contracting.

sive species to plant. When the data were adjusted for differences in planting density as well as for influence of contracting and species difference, a curve of the form $Y = a + b\ (1/X)$ described the relationship quite well (fig. 4).

Actually the peculiar relationship described only indicates that variables other than project size were operating to influence cost. At the same time it points up the danger of taking one variable at a time and making an adjustment for cost. Although it is necessary to plot the data to get a general idea of the relationship, once this is learned the multiple regression technique should be used. By this method, each variable is evaluated with the linear effect of all other variables removed.

### Predicting project costs

At some point in the development of equations to predict costs, a decision must be made as to the level of costs to be predicted. Some managers may want to predict total project costs while others would prefer unit costs—that is, costs per acre. Either plan is possible. The method described here predicts total costs, however, because until better

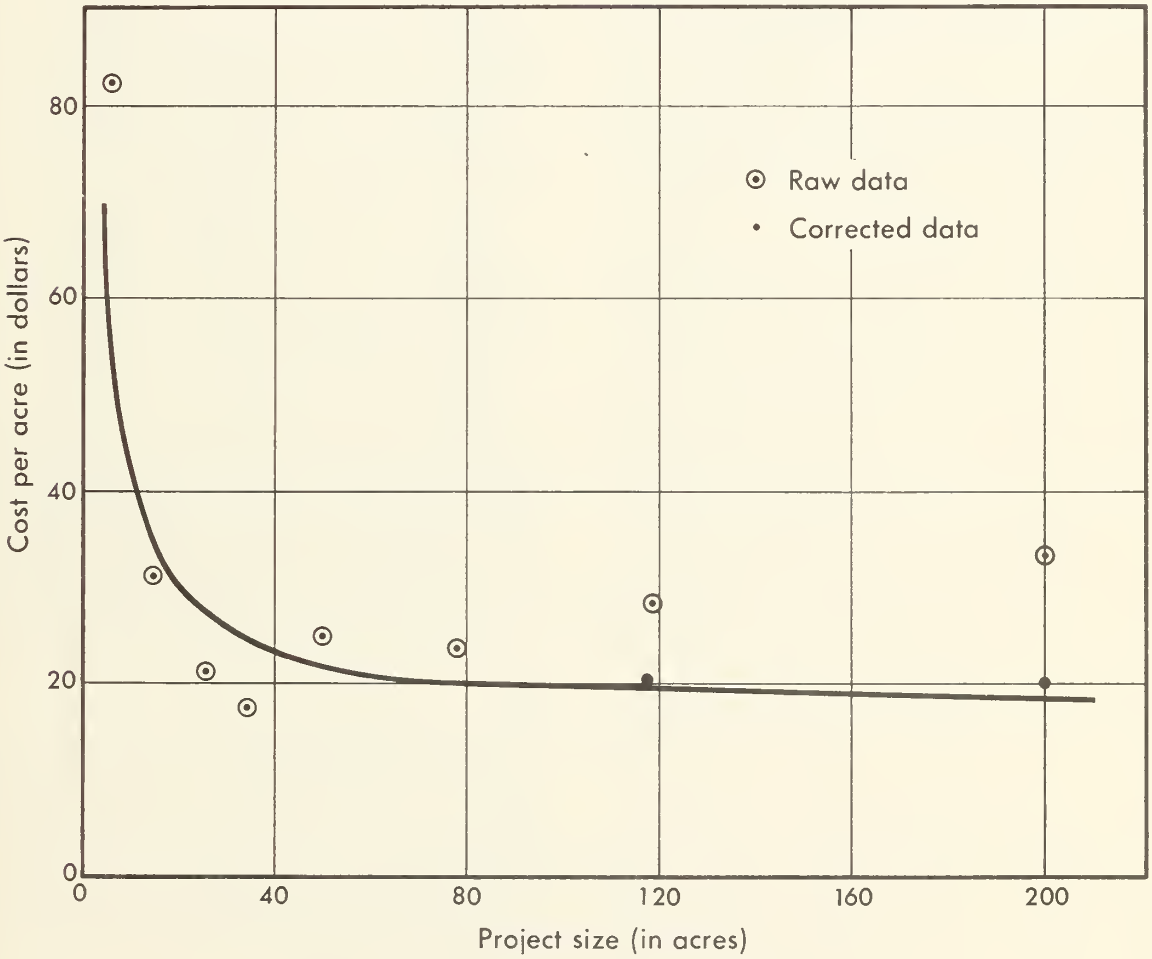

Figure 4. — Relationship of size of an area to cost per acre, in hand planting, showing corrected curve adjusted for differences in planting density, finance class, and species.

data become available, total costs can probably be predicted more accurately. To predict per-acre costs with the data now available, it would be necessary to weight the samples used, since the range of variation is greater for small projects than for larger ones. At present no computer program to carry out the procedure is available for Forest Service equipment. Ultimately, it may be necessary to use a weighting procedure to develop equations to predict per-acre costs. However, it is also possible that the pattern of variation in the present set of data reflects inefficiencies in small project management that will be eliminated as managers make more effective use of the tools of cost control. The weighting procedure will thus be simplified. Since this presentation is aimed primarily at initiating a cost analysis and control program, further discussion of sample weighting will be deferred to a later study, when better data are available.

The preliminary plots and adjustments of data described in the previous section provided a basis for choosing variables for the multiple regression equation. This work revealed that project cost increased with the square of the area and was influenced by planting density. Also, cost was quite well correlated with total trees planted, and there was reason to suspect (1) a small difference in cost between planting done under contract and planting done by Forest Service crews, and (2) a somewhat higher cost for planting white pine than for other species. Further, the amount of brush cover and down material appeared to have an effect. These latter effects could not be accurately evaluated because of the crude way in which brush cover and down material were estimated. However, there appeared to be justification for distinguishing three classes for each item. Finally, it was concluded that transportation should probably be considered a variable (even though it most logically should be estimated as a separate item) because crews usually travel on official time.

In summary, the variables selected for use in the regression are as follows:

| *Nondiscrete variables* | *Discrete variables* |
|---|---|
| Area | Species |
| Planting density | Finance class |
| Total trees planted | Brush cover |
| Transportation | Down material |

The next step was to test the variables by entering them into a multiple variable equation. However, as stated earlier, discrete variables cannot be tested until they have been coded to indicate the comparisons to be made. Since only two or three classes were involved here, coding for comparison was simple.[12]

| *Variable* | *Code assigned* |
|---|---|
| Species: | |
| White pine | +1 |
| Other | −1 |
| Finance class: | |
| Contract | +1 |
| Force account | −1 |
| Brush cover: | |
| Heavy and extra heavy | +1 |
| Medium | 0 |
| Light | −1 |
| Down material: | |
| Heavy and extra heavy | +1 |
| Medium | 0 |
| Light | −1 |

Other necessary adjustments were the transformation of data for area so that total cost was regressed on area$^2$ (see discussion of figure 3) and total trees planted are entered as trees per acre. No special preliminaries are necessary, however, as these operations can be done as the data are fed into the computer.

The actual testing of the variables was accomplished by the computer, using a multiple regression program. The regression program computes the mean values and standard deviations for all the variables, and a correlation matrix showing how the variables correlate with each other. In addition, it provides the following statistics:

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[12] *Only comparisons assuming linear relationships are shown for brush cover and down material. Another comparison was tested assuming a nonlinear relationship. However, this comparison did not add significantly to the regression.*

1. *The regression constant*, $B_0$, which is the $Y$ axis intercept.
2. *The regression coefficient*, which indicates how much the dependent variable (cost) changes with each unit of change in the independent variable when all other variables are held constant at their mean levels. The hidden assumption exists that all the other variables that interact with each independent variable, including factors not measured in the sample, continue to interact as they did in the sample.
3. *The standardized regression coefficient*, which tells how much cost changes in relation to its standard deviation for a change of one standard deviation in the independent variable.
4. *$F$ ratio*, which is the ratio of the mean square for the variable tested to the error mean square.
5. $R^2$, which tells how much of the variation in cost has been accounted for by the regression.
6. *The standard error of the regression*, which is a measure of the accuracy of the mean predicted by the regression equation.

The first two of the statistics listed, the regression constant and the regression coefficient, are used in the solution of the prediction equation. The standardized regression coefficient provides an estimate of the sensitivity of the dependent variable to changes in the independent variables in common units (standard deviations). That is, it tells the analyst how sensitive the cost is to changes in the factors that affect cost.

The $F$ ratio indicates the significance of the variable. An $F$ ratio greater than 1.0 may or may not indicate that some systematic influence is associated with the variable. The larger the $F$ ratio, the less it is likely that the effect measured is due to chance. Values are compared with those in standard $F$-test tables, for the appropriate degrees of freedom. The tables show the levels of $F$ that can be considered significant in standard statistical tests.

The standard error and the $R^2$ are general measures useful in evaluating the results of the analysis.

The computer output is illustrated here in the four regressions that were run initially: (1) trial using only area$^2$ as an independent variable; (2) trial using area$^2$ and planting density (trees planted per acre); (3) trial using the two independent variables in (2) plus the product of the two; and (4) trial using the same variables as in (3) plus total trees planted, the product of area$^2$ and total trees planted, and three discrete variables: species, brush cover, and down material. If finance class had been a significant variable, separate regressions could have been run for contract and force account planting.

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*Trial 1. Regression using only the most important variable, area$^2$*

| | | Area$^2$ |
|---|---|---|
| $B_0$ | = | 665.62 |
| Regression coefficient | = | .145 |
| Standardized regression coefficient | = | .971 |
| $F$ ratio | = | 856.2 |
| $R^2$ | = | .944 |
| Mean project cost for the sample | = | $1,589.36 |
| Standard error | = | 457.53 |

Prediction equation: Project cost less planting stock $= 665.62 + 0.145$ (area$^2$).

Note here the standardized regression coefficient, 0.971. This means that a change of one standard deviation in area$^2$ results in a change in project cost equal to 0.971 of the standard deviation in project cost, indicating that project cost is highly sensitive to a change in area.

### *Trial 2. Regression using the two most important variables, area$^2$ and planting density*

$B_0 = -102.59$

| | | Area$^2$ | Planting density |
|---|---|---|---|
| Regression coefficient | = | 0.147 | 1.83 |
| Standardized regression coefficient | = | .980 | .125 |
| $F$ ratio | = | 1,172.8 | 19.0 |

$R^2 = 0.959$

Standard error = 393.36

Project cost less planting stock = −102.59 + 0.147 (area$^2$) + 1.83 (trees planted per acre).

Note that as a second variable was entered, the regression coefficient for area$^2$ increased slightly, as did the standardized regression coefficient; also, the standard error decreased.

### *Trial 3. Regression adding the product of area$^2$ and planting density*

(Since cost increased with an increase in area$^2$ or in planting density, the product of the two variables was used.)

$B_0 = 159.85$

| | Area$^2$ | Planting density | Area$^2$ × planting density |
|---|---|---|---|
| Regression coefficient | 0.060 | 0.997 | 0.00025 |
| Standardized regression coefficient | .402 | .068 | .587 |
| $F$ ratio | 9.19 | 6.07 | 19.7 |

$R^2 = 0.971$

Standard error=335.59

Project cost less planting stock=159.85+0.060 (area$^2$) +0.997 (trees planted per acre) + 0.00025 (area$^2$ × trees planted per acre).

### *Trial 4. Regression adding transportation weight (vehicle miles), total trees planted, and discrete variables*

(This regression was run stepwise; the $F$ ratio at which variables could be entered or removed was set at 1.5. Only total trees planted and down material class added significantly to the regression. Transportation weight, species difference, and brush cover were not significant ($F$ ratio less than 1.5).

$B_0 = 93.81$

| | Area$^2$ | Area$^2$ × planting density | Total trees planted | Area$^2$ × total trees planted | Down material |
|---|---|---|---|---|---|
| Regression coefficient | 0.100 | 0.00022 | 0.045 | 0.0000007 | 165.21 |
| Standardized regression coefficient | .669 | .511 | .530 | .383 | .065 |
| $F$ ratio | 18.31 | 4.00 | 26.13 | 5.17 | 10.48 |

$R^2 = 0.982$

Standard error = 272.15

Project cost = 93.81 + 0.100 (area$^2$) +0.00022 (area$^2$ × trees planted per acre) +0.045

(total trees planted) +0.0000007 (total trees planted × $\text{area}^2$).

Adjustment to be made on the average project (58.3 acres) for down material class:

Heavy down material, add $165.21
Medium down material, no change
Light down material, subtract $165.21

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## Evaluating Accuracy of Cost Estimates

Of real concern to the user of the cost prediction model is the accuracy with which costs can be estimated for a particular project under particular circumstances. It should be recognized at the outset that the equations developed are usable only when the projects being estimated are within the range of circumstances included in the sample. Moreover, the closer the conditions in the project to be estimated approach the average of the conditions included in the sample, the more accurate will be the estimate. To illustrate, let us suppose that planting projects in the sample ranged in size from 4 acres to 275 acres, and avg. $\text{area}^2 \left(\sqrt{\text{area}^2/n}\right)$ was 80 acres. Then, the formula for planting costs should not be used for projects smaller than 4 acres or larger than 275 acres, and the most accurate results will be achieved when projects to be estimated are nearest to 80 acres in size. Means and standard deviations as well as the ranges for all variables used in the illustrations are presented in appendix C.

Assuming the prediction equations are to be used to estimate project cost under conditions that are average for the sample, the standard error of estimate, $S_{y\,.\,x_1x_2\,\ldots\,x_m}$, which is the square root of the variance of $Y'$, is a valid measure of accuracy.

However, in addition to estimating costs for conditions that are average for the sample, the forester may want to know how accurately he can estimate the cost of a specific project that departs from the average. The error associated with this type of estimate is the *standard error of forecast*, which is the square root of the variance of the forecast. The equation for computing the variance of forecast is as follows:

$$S^2_{\hat{y}} = S^2_{y.x_1x_2\cdots x_m} \left(1 + \frac{1}{n} + \sum_{i=1}^{m}, C_{ii}X_i^2 + 2 \sum_{i>j}^{m} \sum^{m}, C_{ij}X_{ij}\right)$$

The $n$ in the equation is the number of samples in the regression. Here the $X$ values are the values of the independent variables for which the forecast is to be made, stated as departures from the means of the variable calculated for the sample. (For example, if $X$ were planting density and the density planned for the project to be forecast was 400 trees per acre compared to a sample mean planting density of 415 trees per acre, the value of $X$ in the equation would be $-15$.) The $C$ values for each variable can be obtained from the inverse matrix associated with the regression used, and developed by the computer. The $i$ values associated with each $C$ indicate the column and row in the matrix from which the $C$ value is to be taken.

The difficulty involved in computing the standard error of forecast is apparent from the formula; that is, if there are many variables in the regression equation, a complex expression results. In addition, the formula clarifies two other principles stated earlier: (1) The fact that $X$ values are departures from the mean explains why projects that approach the mean of the sample can be forecast more accurately than those that fall out at the extremes of the sample ranges; and (2) the formula explains why a variable having an $F$ ratio that is not significant at or approaching the 5-percent level should not be included in the regression, since evidently the variance added by such a variable may actually reduce the accuracy of a forecast.

The equation with three variables (Trial 3) may be used to illustrate the computation of the standard error of forecast. The following tabulation indicates the development of the $X$ values:

| *Variable* | *Mean value* | *Value for project to be forecast* | *Difference ($X$)* |
|---|---|---|---|
| $X_1$ = area$^2$ | 6,354 | 3,600 | -2,754 |
| $X_2$ = planting density | 415 | 400 | -15 |
| $X_3$ = area$^2$ × planting density | 2,534,082 | 1,440,000 | -1,094,082 |

$n - 53$

$S^2_{y.x_1,x_2,x_3} = 110{,}762$

From the inverse matrix:

$C_{11} = 0.00000000349$ $\quad C_{12} = 0.00000003326$

$C_{22} = .00000145$ $\quad C_{23} = -.000000000939$

$C_{33} = .000000000000028$ $\quad C_{13} = -.0000000000975$

$$S^2_{\hat{y}} = 110{,}762 \left[1 + \frac{1}{53} + C_{11}\,(X^2_1) + C_{22}\,(X^2_2) + C_{33}\,(X^2_3) + 2C_{12}\,(X_1X_2) + 2C_{13}\,(X_1X_3) + 2C_{23}\,(X_2X_3)\right]$$

Substituting the appropriate $C$ and $X$ values, and solving,

$S^2_{\hat{y}} = 112{,}932$

$S_{\hat{y}} = \$336.05$

That is, the analyst would expect his estimate of cost for the project to be within \$336.05 of the actual cost two times out of three.

At this point the question might be asked whether the equations illustrated (Trials 1 to 4) might be improved with further analysis. The technical answer to that question probably is "yes." One check that can be made is to compute a predicted cost for each project in the sample, and plot the difference between the actual and predicted cost over the range of costs. If the residuals are uniformly distributed along the line representing the range in costs, this would suggest a good analysis. However, if large residuals were associated with small or large projects or were otherwise nonuniformly distributed, this would suggest that more work was desirable. As shown in figure 5, the residuals for the last equation shown (Trial 4) are quite uniformly distributed. (It is also evident from figure 5 that the variance associated with small projects was larger than that associated with the big projects; this fact partially explains why it is better to predict total project costs than per-acre costs at present.) In practical terms, the experience of this analysis tells the manager that the next step might well be to develop a better measure of accessibility, as well as a better measure of down material and perhaps of brush cover also. In fact it tells him more than that. It says there is probably an opportunity to improve administrative efficiency, particularly in the small jobs.

## Analysis of Sensitivity

Two other questions frequently asked by managers concerned about costs are

1. What elements in a specific type of work should management watch closest?
2. Which types of work in the overall program require the closest supervisory attention?

A sensitivity analysis can help answer these questions.

### Sensitivity analysis within a particular type of work

The elements in the particular kind of work (planting, thinning, prescribed burning) that should be most closely watched are normally those controllable factors that have the greatest effect on cost. The object of sensitivity analysis is to determine how sensitive the dependent variable (cost) is to changes in each of the independent variables (factors that affect cost), with the influence of other independent variables removed.

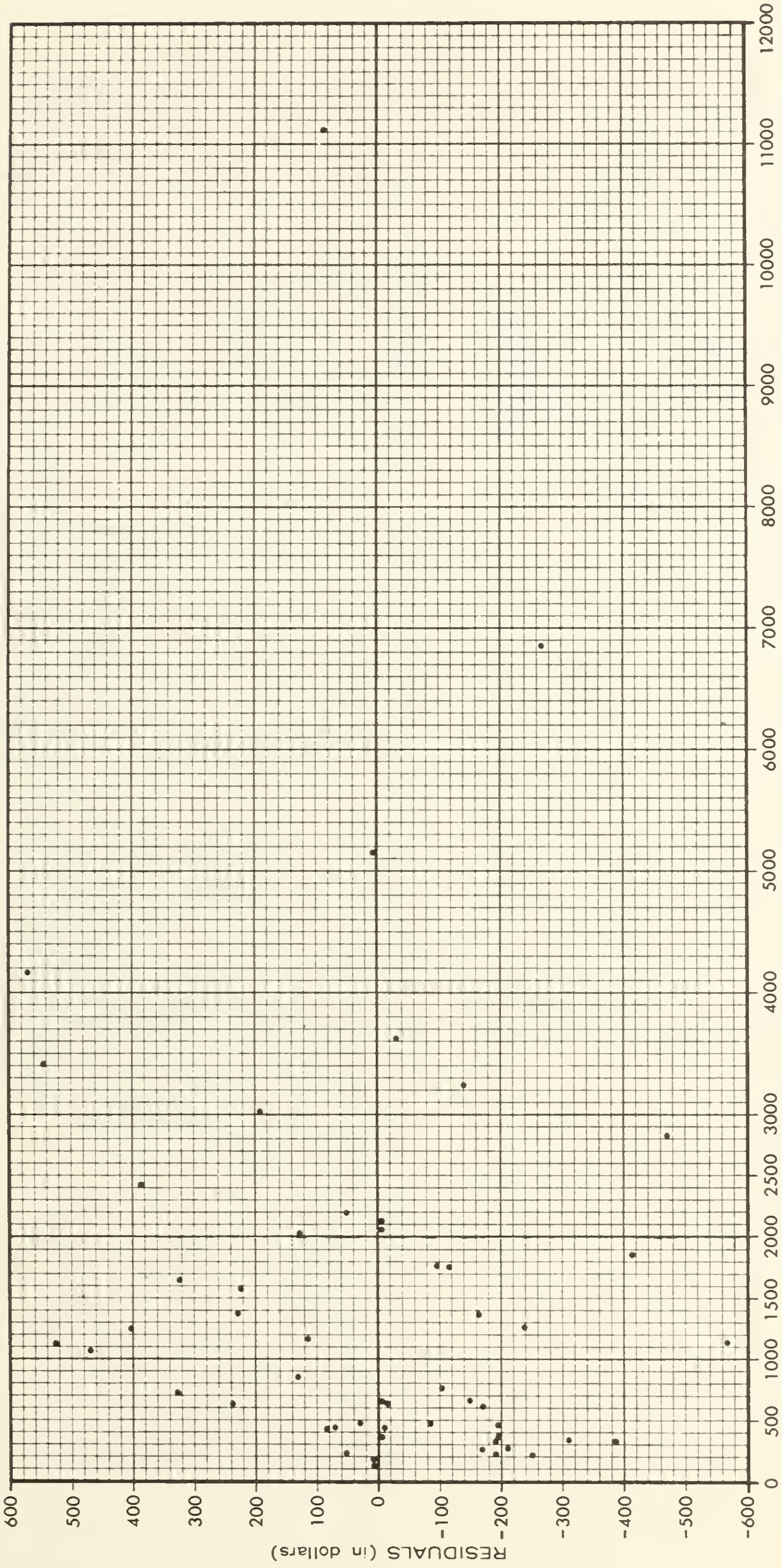

Figure 5. — Distribution of residuals over project costs.

Other data developed in the regression analyis procedure described in this paper will permit the manager to draw some conclusions about the responsiveness of the dependent variable (cost) to changes in the independent variables. However, three limitations must be recognized:

1. The range of one or more of the variables measured in the sample may be so small that a true picture of sensitivity is not reflected in the data. For example, cost of planting may be very sensitive to changes in number of trees planted per acre, but there may have been so little variation in number of trees planted that the significance of the variable cannot be evaluated.

2. The most sensitive variables may be those that cannot easily be varied or controlled. For example, the most important factor influencing the cost of prescribed burning may turn out to be sudden and unpredictable weather changes.

3. Sensitivity analysis breaks down where there are strong interactions between independent variables, so that the products of variables have to be used in the regression equation. To illustrate, the evaluation of the influence of a variable *C*, which is the product of variables *A* and *B* with the influence of *A* and *B* held constant, becomes highly theoretical. This limitation applies to the data used in this discussion. Consequently no attempt will be made to illustrate further this aspect of sensitivity analysis.

However, recognizing the above limitations, evaluations of sensitivity can still be made when the data permit. When stepwise regressions are used, the order in which variables are added or removed gives a general idea of the relative importance of the variables. Also, other measures of sensitivity exist. These are, first, the regression coefficients themselves, which tell how much the dependent variable changes for each unit of change in an independent variable. Second are the standardized regression coefficients. These provide a measure in standardized or common units (standard deviations) of the capacity of the different independent variables to influence cost. As already mentioned, these standardized regression coefficients are an estimate of the change in cost in relation to the standard error of cost for a change in an independent variable relative to the standard error of that independent variable. Each independent variable is evaluated with the influence of all other independent variables removed. Managers will want to consider both the regression coefficients and the standardized regression coefficients in making judgments about which variables to attempt to manipulate or control to achieve lower costs.

Another sensitivity measure that can be used is the coefficient of partial correlation. This statistic describes the same relationship as the standardized regression coefficient but in different terms; the limitations enumerated above apply here as well. The coefficient of partial correlation is a relative measure of the association between the dependent variable and a given independent variable, eliminating the effect of other independent variables. In other words, it measures how much a particular variable reduces the variation in the dependent variable after the effect of the other variables has been taken out. It is used in preference to the simple correlation coefficient *r* to uncover relationships that may otherwise be obscured because of the way the independent variables may be intercorrelated. For example, if number of trees planted per acre were negatively correlated with size of area, a decrease in size of area might obscure the effect of an increase in planting density on project cost.

### Sensitivity analysis of the annual program

The analysis of costs can also be carried to the point of indicating which jobs in the annual program of a Forest offer the greatest opportunity for savings through closer supervision. These would normally be the jobs that account for the greatest amount of deviation in average per-acre cost of the total program, considering the size of the job in the total program and the deviation expected in average costs.

A form of sensitivity analysis is illustrated in table 4. The annual program for this sample Forest includes treating 18,500 acres in different ways. The analysis indicates that a third of the variation in average program cost per acre can be expected to result from the conduct of the thinning job. It is in this job that opportunities for cost savings probably are greatest.

Table 4.—**Sensitivity analysis for a Forest program**

| Type of work | Average cost per acre[1] | Expected deviation from average cost[2] | Area to be treated | Ratio of area treated to total area in program | Effect of deviation on average per-acre cost of total program[3] |
|---|---|---|---|---|---|
| | | Percent | Acres | | Percent |
| Site preparation: | | | | | |
| Prescribed burn | $10.21 | 50 | 3,000 | 0.16 | $\frac{0.50(0.16)(10.21)}{27.10} \times 100 = $ [4]3.0 |
| Dozer piling | 40.14 | 20 | 2,000 | .11 | $\frac{0.20(0.11)(40.14)}{27.10} \times 100 = $ 3.3 |
| Other | 24.10 | 20 | 400 | .02 | .4 |
| Planting: | | | | | |
| Hand | 29.91 | 30 | 3,000 | .16 | 5.3 |
| Machine | 21.89 | 20 | 1,000 | .05 | .8 |
| Thinning | 30.03 | 30 | 5,500 | .30 | 10.0 |
| Pruning | 39.95 | 30 | 2,000 | .11 | 4.9 |
| Mistletoe control | 15.07 | 50 | 1,600 | .09 | 2.5 |
| Total program | $27.10 | | 18,500 | 1.00 | 30.2 |

[1] Data from past cost records.

[2] Data derived from analysis of previous cost records, from case studies, or if no information is available, from judgment by experience.

[3] Computation is illustated for first two items only.

[4] Interpretation: Even though the deviation from the average prescribed burning costs is high (50 percent), the average per-acre cost is low ($10.21) in relation to other activities and to the average ($27.10). Considering this and the fact that only 3,000 acres (or 16 percent of the program total) are to be burned, prescribed burning is only contributing 3 percent of the 30.2 percent variation in the average per-acre cost for the program.

# APPENDIX A

The objective of the Northern Region is first of all to collect, for each stand or area being considered for treatment, all the information needed for a decison on the kind of treatment needed and the treatment that should have priority. The second objective is to reduce the raw field data into its most usable form and incorporate it into a resource information system that allows for easy retrieval when the data is needed in decision making or reporting. It is essential that the information be accurate; that is, it should be edited for inconsistencies, a job that can be done by machine. Also, the information system should provide for updating as stands or areas are treated and their condition is changed.

Figure 6 shows the data collected by a stage two inventory crew on a stand on the Kootenai National Forest. The data on the field or plot sheet were punched on cards and machine edited (fig. 7).

To facilitate decision making, the information has been summarized to accent the important characteristics of the stand. Figure 8 summarizes the trees by class (potential crop trees, excess trees, sound cull trees, or dead trees), diameter class, and species.

The second summary (fig. 9) is designed to bring out conditions of sawtimber stands. The emphasis in this summary is on tree risk class (high or low risk, mature timber or growing stock), tree class (potential crop or excess trees) and volume per acre by species of sawtimber trees.

The third summary (fig. 10) is concerned with growth rates. Note that this summary gives a qualitative picture of growth as well as a quantitative summary. Growth has been summarized both by tree class (potential crop trees and all trees), and by broad tree sizes (sawtimber and pole). Volume 10 years ago is shown along with present volume and incremental growth rates.

The fourth summary (fig. 11) presents statistical data useful to the manager or analyst. In addition to data on the reliability of the statistics presented, the summary includes a calculation of the number of plots needed to give a sampling error of 20 percent. This information is used in planning future stand surveys.

Finally a summary is prepared to be incorporated into the resource information system. The data fed into the system for this particular stand are shown in figure 12. In addition, the figure shows the items of information required for other kinds of stands. The codes used will not be described here as they are available in Northern Rocky Mountain Region Timber Management Control Handbook.[13] The procedure for updating this record is also described in the Handbook.

**Figure 6. — Field data form used to collect data on each stand or area likely to be included in the forest management program.**

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[13] *U.S. Forest Service, Northern Region. Timber management control handbook 2411.15-R1. 1966.*

RI-2410-15 (REVISED 3/67)
PAGE 1 OF 1 PAGES

| | | | |
|---|---|---|---|
| STAND OR AREA RECORD AND ANALYSIS SHEET<br>(REFERENCE FSH 2411.14 RI) | STATE (1-2) 2 5 | COUNTY (3-5) 0 5 3 | FOREST (6-7) 1 4 |
| | WORKING CIRCLE (8) 1 | BLOCK (9) 7 | COMPARTMENT (10-11) 2 6 |
| | SUBCOMPARTMENT (12) 7 | STAND OR AREA (13-14) 0 5 | |

| | | | | |
|---|---|---|---|---|
| ND ASS (15) 1 | MULTIPLE USE ZONE (16-17) 2 1 | SOIL CLASS (18-21) 0 0 1 4 | HABITAT TYPE (22-23) 2 2 | PHYSIOGRAPHIC SITE (24) 2 |
| ELEVATION (25-26) 4 6 | OPE 7) 2 | ASPECT (28) 5 | AREA (29-31) 1 5 0 | NUMBER OF PLOTS (32-34) 0 0 8 |
| TOTAL NUMBER OF TREES (35-38) 0 0 4 9 | BAF (39-40) 4 0 | ACCESSIBILITY (41) 1 | | |

RECORD OF FIELD DATA

| PLOT | TREE CLASS | SPECIES | NUMBER TREES | D.B.H. | HEIGHT | GROWTH RATE | GROWTH TREND | CROWN CLASS | CROWN RATIO | AGE | DAMAGE | DEFECT | CLEAR LENGTH | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| )-52) | (53-54) | (55-57) | (58-59) | (60-62) | (63-65) | (66-67) | | | | | | | | |
| 01 | 11 | 122 | 01 | 088 | 053 | 12 | 3 | 3 | 2 | 042 | 00 | 0 | 00 | "site" |
| | 11 | 202 | 01 | 065 | 046 | 15 | 2 | 3 | 1 | 036 | 00 | 0 | 00 | |
| | 21 | 202 | 01 | 037 | 032 | 07 | 3 | 4 | 1 | 038 | 00 | 0 | 00 | |
| | 50 | 202 | 04 | 010 | 002 | | | | | | | | | |
| 02 | 11 | 122 | 01 | 055 | 038 | 09 | 2 | 3 | 2 | 038 | 00 | 0 | 00 | |
| | 50 | 202 | 01 | 010 | 004 | | | | | | | | | |
| | 50 | 202 | 02 | 010 | 001 | | | | | | | | | |
| 03 | 11 | 122 | 01 | 13[illegible] | 054 | 21 | 3 | 2 | 2 | 048 | 00 | 0 | 00 | "site" |
| | 21 | 073 | 01 | 127 | 074 | 12 | 3 | 2 | 2 | 060 | 00 | 0 | 00 | |
| | 50 | 202 | 04 | 010 | 001 | | | | | | | | | |
| 04 | 11 | 122 | 01 | 122 | [illegible] | 14 | 2 | 2 | 2 | 05[illegible] | 00 | 0 | 00 | |
| 05 | 11 | 122 | 01 | 092 | 06[illegible] | 10 | 3 | 5 | 2 | 065 | 00 | 0 | 04 | |
| | 21 | 202 | 01 | 028 | 026 | 08 | 3 | 4 | 1 | 032 | 00 | 0 | 00 | |
| | 50 | 202 | 07 | 010 | 001 | | | | | | | | | |
| 06 | 11 | 122 | 01 | 070 | 063 | 14 | 3 | 3 | 2 | 061 | 00 | 0 | 00 | |
| | 11 | 122 | 01 | 072 | 060 | 04 | 3 | 3 | 2 | 061 | 00 | 0 | 00 | |
| | 11 | 122 | 01 | 102 | 065 | 08 | 3 | 3 | 2 | 068 | 00 | 0 | 00 | |
| | 11 | 122 | 01 | 125 | [illegible] | 13 | 3 | 3 | 2 | 065 | 00 | 0 | 00 | |
| | 11 | 122 | 01 | 045 | [illegible] | 05 | 3 | 3 | 2 | [illegible] | [illegible] | | | |
| | 50 | 073 | 01 | 060 | 053 | 03 | | | | | | | | |
| | 50 | 122 | 01 | 034 | 015 | | | | | | | | | |
| | 50 | 202 | 01 | 05[illegible] | [illegible] | 03 | | | | | | | | |
| 07 | 11 | 122 | 01 | 14[illegible] | [illegible] | 14 | 3 | 2 | [illegible] | [illegible] | [illegible] | | | |
| | 21 | 202 | 01 | 070 | [illegible] | 09 | 3 | 3 | 2 | [illegible] | [illegible] | | | |
| | 50 | 202 | [illegible] | 010 | 001 | | | | | | | | | |
| | 50 | 202 | 01 | [illegible] | [illegible] | | | | | | | | | |
| [illegible] | [illegible] | 202 | 01 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | | [illegible] | |
| | [illegible] | [illegible] | [illegible] | [illegible]41 | 040 | [illegible]4 | [illegible] | 4 | 2 | [illegible] | [illegible] | | | |
| | 5[illegible] | [illegible]2 | [illegible]1 | [illegible] | [illegible]2 | | | | | | | | | |

(Front)

(OVER)

1. PHOTO IDENTIFICATION NUMBER

2. SITE TREES

A. SPECIES 122 D.B.H. 8.8 HEIGHT 53 AGE 42 CROWN CLASS 3
B. SPECIES 122 D.B.H. 13.1 HEIGHT 54 AGE 48 CROWN CLASS 2
C. SPECIES 122 D.B.H. 9.2 HEIGHT 68 AGE 68 CROWN CLASS 2

3. GENERAL OBSERVATIONS BY MANAGEMENT CLASSES

A. IF A MATURE STAND:
(1) HAS STAND BEEN LOGGED? ........ IF SO, ABOUT WHEN? ........
(2) HOW MUCH LONGER CAN STAND BE HELD ON STUMP WITHOUT SERIOUS LOSS? ........
(3) MORTALITY: HEAVY ........ MEDIUM ........ LIGHT ........
(4) NUMBER WINDFALLS PER ACRE ........ AVERAGE SIZE ........ NUMBER SNAGS PER ACRE ........ AVERAGE SIZE ........

B. IF AN IMMATURE STAND:
(1) IS IT VIGOROUS? ........ RETARDED? PARTIALLY STAGNATED? ........
(2) DOES IT HAVE TWO OR MORE IMMATURE STORIES? YES DOES IT HAVE A MATURE OVERSTORY? NO
(3) IS STAND CLUMPY? YES PRINCIPAL CANOPY: SAW ........ POLE ✓ SAPLING ✓ SEEDLING ........
(4) DAMAGE: DISEASE ........ INSECTS ........ ANIMAL ........ OTHER ........ IS IT LIGHT? ........ MEDIUM? ........ HEAVY? ........

C. IF A NONSTOCKED AREA:
(1) WHAT WAS PREVIOUS FOREST TYPE? ........ WHAT CAUSED NONSTOCKED CONDITION? ........
(2) ESTIMATED PERCENT GENERAL GROUND COVER: BARREN ........ SOD ........ DEBRIS ........ DUFF ........ LOW BRUSH ........ HIGH BRUSH ........
(3) NUMBER SNAGS PER ACRE ........ AVERAGE D.B.H. ........ NUMBER WINDFALLS PER ACRE ........ AVERAGE D.B.H. ........
(4) DOES SITE NEED PREPARATION BEFORE PLANTING? ........ WHAT KIND? ........
(5) ANIMAL USE: DOMESTIC ........ WILD ........ USE: HEAVY ........ MEDIUM ........ LIGHT ........
(6) DOES AREA HAVE OVERWOOD? ........ WHAT KIND? ........

4. EROSION

DOES GROUND HAVE 75 PERCENT OR MORE COVER? YES EVIDENCE OF RILLS NO GULLIES NO

5. DO YOU BELIEVE THIS TRANSECT SAMPLED STAND ADEQUATELY? YES COMMENTS: Stand is clumpy in SPOTS BUT plots represent a good cross section of stan

6. GENERAL STATEMENT AND EXAMINER'S PRESCRIPTION

THRIFTY stand in 40-60 year age class but growth is falling off in majority of crop trees.
OFFERS A GOOD OPPORTUNITY FOR A MIXED STAND FOLLOWING THINNING

7. ACCESSIBILITY: WHAT ARE PROBLEMS OF ACCESS RELATED TO YOUR PRESCRIPTION?

NONE

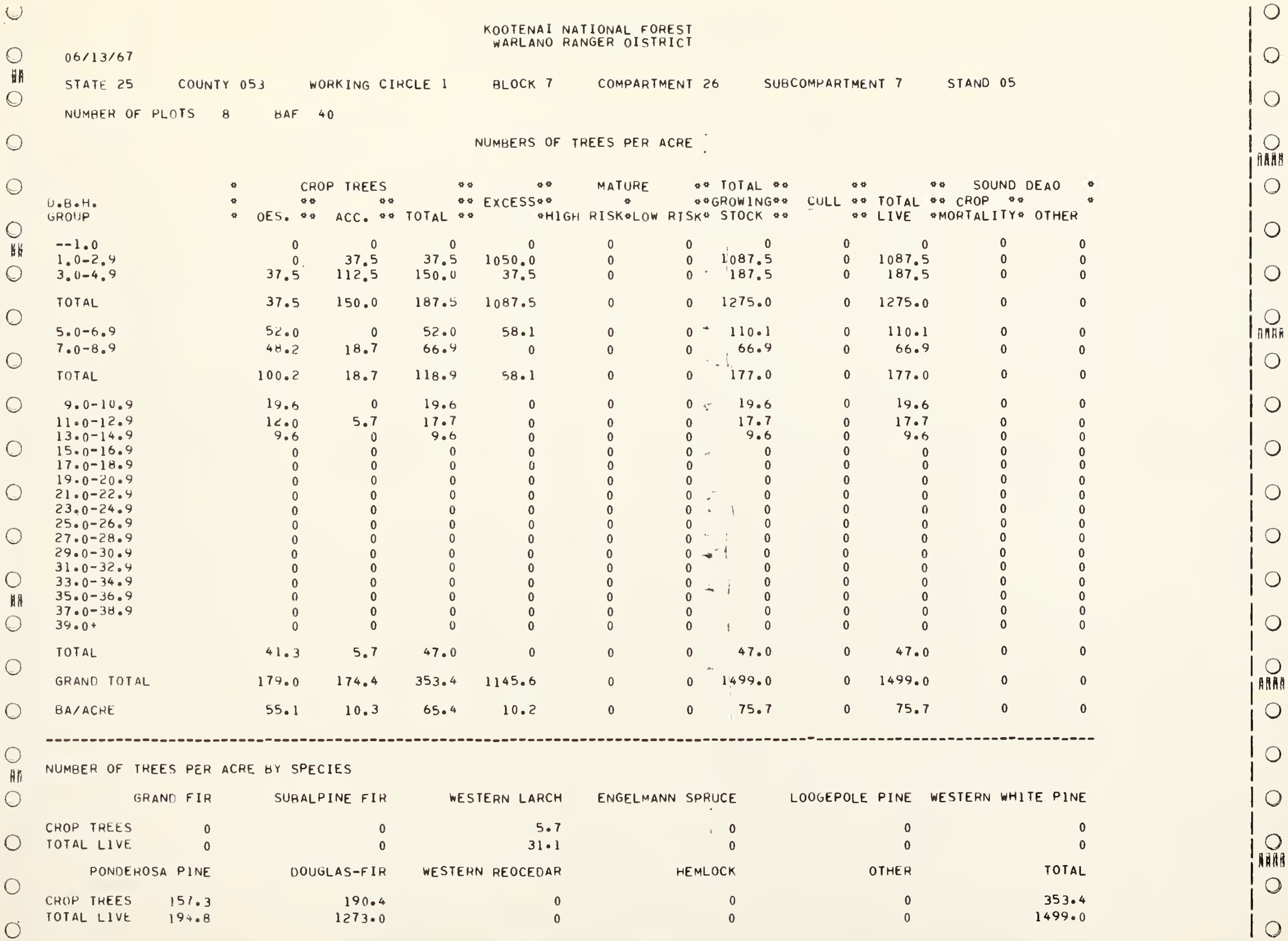
8. ANALYST'S PRESCRIPTION

Precommercial Thinning - Pruning IF Financing AVAILABLE

| | | | |
|---|---|---|---|
| 9. FIELDWORK BY<br>LEWIS | DATE<br>4/12/67 | ANALYSIS BY<br>CLARK | DATE<br>4/14/67 |

```
                                          KOOTENAI NATIONAL FOREST
                                           WARLAND RANGER DISTRICT
 06/13/67

 STATE 25      COUNTY 053     WORKING CIRCLE 1     BLOCK 7     COMPARTMENT 26     SUBCOMPARTMENT 7     STAND 05

 NUMBER OF PLOTS   8      BAF  40

                                                 EDIT OF DATA

NO ERRORS
```

Figure 7. — Edit program summary.



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                                                  KOOTENAI NATIONAL FOREST
                                                   WARLANO RANGER OISTRICT
 06/13/67

 STATE 25     COUNTY 053     WORKING CIRCLE 1     BLOCK 7     COMPARTMENT 26     SUBCOMPARTMENT 7     STAND 05

 NUMBER OF PLOTS   8     BAF  40

                                                  NUMBERS OF TREES PER ACRE

                         *        CROP TREES        **        **      MATURE       ** TOTAL **          **        **    SOUND DEAO    *
D.B.H.                   *       **        **       ** EXCESS**          *         **GROWING**  CULL ** TOTAL ** CROP   **          *
GROUP                    *  OES. **   ACC. ** TOTAL **         *HIGH RISK*LOW RISK* STOCK **        ** LIVE   *MORTALITY* OTHER

 --1.0                        0         0         0         0         0         0         0       0         0         0         0
 1.0-2.9                      0      37.5      37.5    1050.0         0         0    1087.5       0    1087.5         0         0
 3.0-4.9                   37.5     112.5     150.0      37.5         0         0     187.5       0     187.5         0         0

 TOTAL                     37.5     150.0     187.5    1087.5         0         0    1275.0       0    1275.0         0         0

 5.0-6.9                   52.0         0      52.0      58.1         0         0     110.1       0     110.1         0         0
 7.0-8.9                   48.2      18.7      66.9         0         0         0      66.9       0      66.9         0         0

 TOTAL                    100.2      18.7     118.9      58.1         0         0     177.0       0     177.0         0         0

  9.0-10.9                 19.6         0      19.6         0         0         0      19.6       0      19.6         0         0
 11.0-12.9                 12.0       5.7      17.7         0         0         0      17.7       0      17.7         0         0
 13.0-14.9                  9.6         0       9.6         0         0         0       9.6       0       9.6         0         0
 15.0-16.9                    0         0         0         0         0         0         0       0         0         0         0
 17.0-18.9                    0         0         0         0         0         0         0       0         0         0         0
 19.0-20.9                    0         0         0         0         0         0         0       0         0         0         0
 21.0-22.9                    0         0         0         0         0         0         0       0         0         0         0
 23.0-24.9                    0         0         0         0         0         0         0       0         0         0         0
 25.0-26.9                    0         0         0         0         0         0         0       0         0         0         0
 27.0-28.9                    0         0         0         0         0         0         0       0         0         0         0
 29.0-30.9                    0         0         0         0         0         0         0       0         0         0         0
 31.0-32.9                    0         0         0         0         0         0         0       0         0         0         0
 33.0-34.9                    0         0         0         0         0         0         0       0         0         0         0
 35.0-36.9                    0         0         0         0         0         0         0       0         0         0         0
 37.0-38.9                    0         0         0         0         0         0         0       0         0         0         0
 39.0+                        0         0         0         0         0         0         0       0         0         0         0

 TOTAL                     41.3       5.7      47.0         0         0         0      47.0       0      47.0         0         0

 GRAND TOTAL              179.0     174.4     353.4    1145.6         0         0    1499.0       0    1499.0         0         0

 BA/ACRE                   55.1      10.3      65.4      10.2         0         0      75.7       0      75.7         0         0

------------------------------------------------------------------------------------------------------------------------------

NUMBER OF TREES PER ACRE BY SPECIES

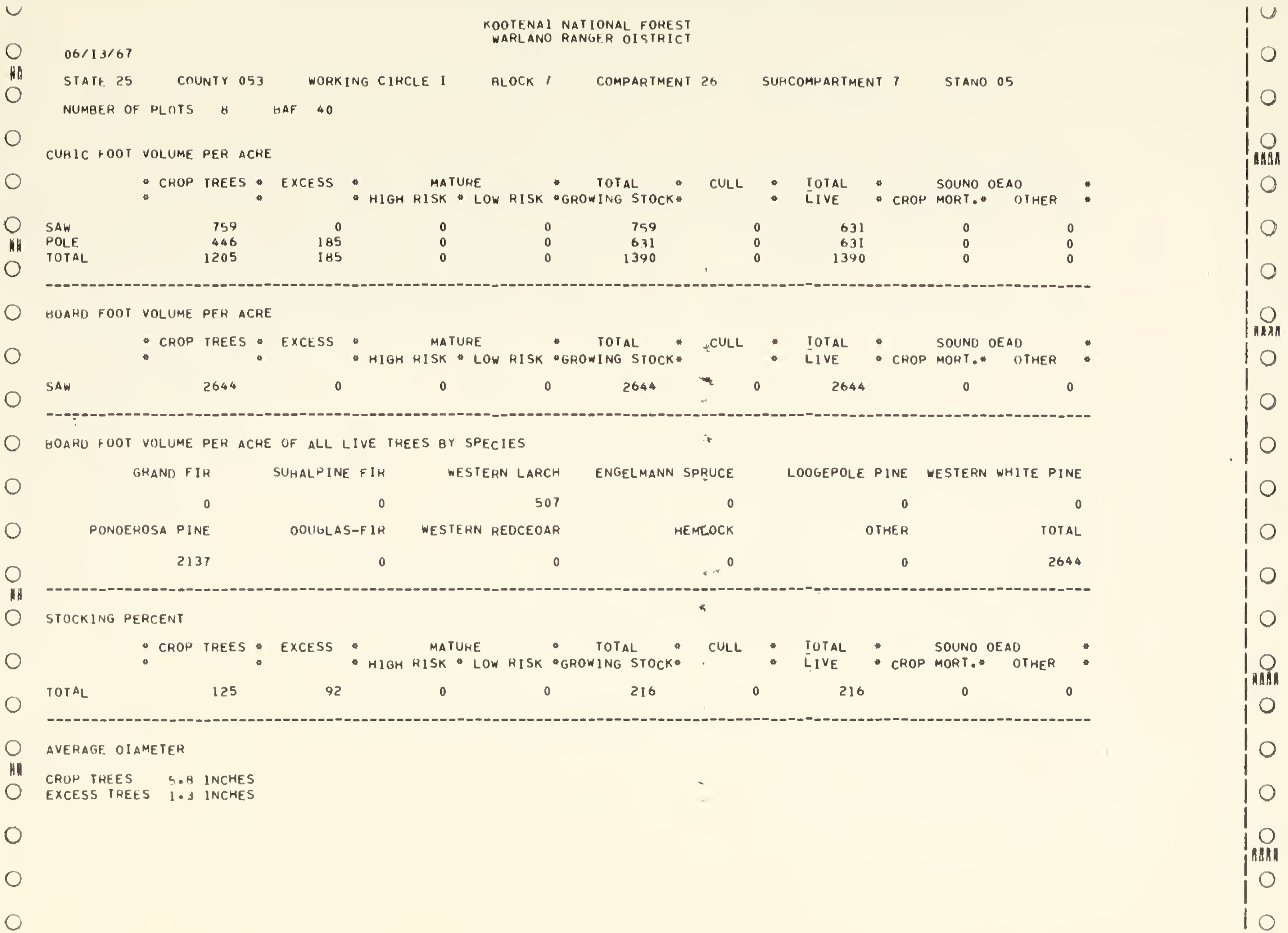
           GRAND FIR        SUBALPINE FIR        WESTERN LARCH    ENGELMANN SPRUCE      LOOGEPOLE PINE  WESTERN WHITE PINE

CROP TREES         0                    0                  5.7                   0                   0                   0
TOTAL LIVE         0                    0                 31.1                   0                   0                   0

      PONDEROSA PINE          DOUGLAS-FIR     WESTERN REOCEDAR             HEMLOCK               OTHER               TOTAL

CROP THEES     157.3                190.4                    0                   0                   0               353.4
TOTAL LIVE     194.8               1273.0                    0                   0                   0              1499.0
```

Figure 8. — Summary emphasizing tree quality and size in immature stands.



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                                                     KOOTENAI NATIONAL FOREST
                                                      WARLAND RANGER DISTRICT
  06/13/67

  STATE 25      COUNTY 053     WORKING CIRCLE I     BLOCK 7     COMPARTMENT 26     SUBCOMPARTMENT 7     STAND 05

  NUMBER OF PLOTS   8     BAF  40

CUBIC FOOT VOLUME PER ACRE

           * CROP TREES *  EXCESS  *        MATURE        *   TOTAL   *   CULL   *  TOTAL   *      SOUND DEAD       *
           *            *          * HIGH RISK * LOW RISK *GROWING STOCK*        *  LIVE    * CROP MORT.*   OTHER   *

SAW               759          0          0          0         759          0         631         0          0
POLE              446        185          0          0         631          0         631         0          0
TOTAL            1205        185          0          0        1390          0        1390         0          0
------------------------------------------------------------------------------------------------------------------

BOARD FOOT VOLUME PER ACRE

           * CROP TREES *  EXCESS  *        MATURE        *   TOTAL   *   CULL   *  TOTAL   *      SOUND DEAD       *
           *            *          * HIGH RISK * LOW RISK *GROWING STOCK*        *  LIVE    * CROP MORT.*   OTHER   *

SAW              2644          0          0          0        2644          0        2644         0          0
------------------------------------------------------------------------------------------------------------------

BOARD FOOT VOLUME PER ACRE OF ALL LIVE TREES BY SPECIES

          GRAND FIR        SUBALPINE FIR       WESTERN LARCH    ENGELMANN SPRUCE      LODGEPOLE PINE  WESTERN WHITE PINE

                  0                    0                 507                   0                   0                   0

      PONDEROSA PINE           DOUGLAS-FIR    WESTERN REDCEDAR             HEMLOCK               OTHER               TOTAL

               2137                    0                   0                   0                   0                2644
------------------------------------------------------------------------------------------------------------------

STOCKING PERCENT

           * CROP TREES *  EXCESS  *        MATURE        *   TOTAL   *   CULL   *  TOTAL   *      SOUND DEAD       *
           *            *          * HIGH RISK * LOW RISK *GROWING STOCK*        *  LIVE    * CROP MORT.*   OTHER   *

TOTAL             125         92          0          0         216          0         216         0          0
------------------------------------------------------------------------------------------------------------------

AVERAGE DIAMETER

CROP TREES    5.8 INCHES
EXCESS TREES  1.3 INCHES
```
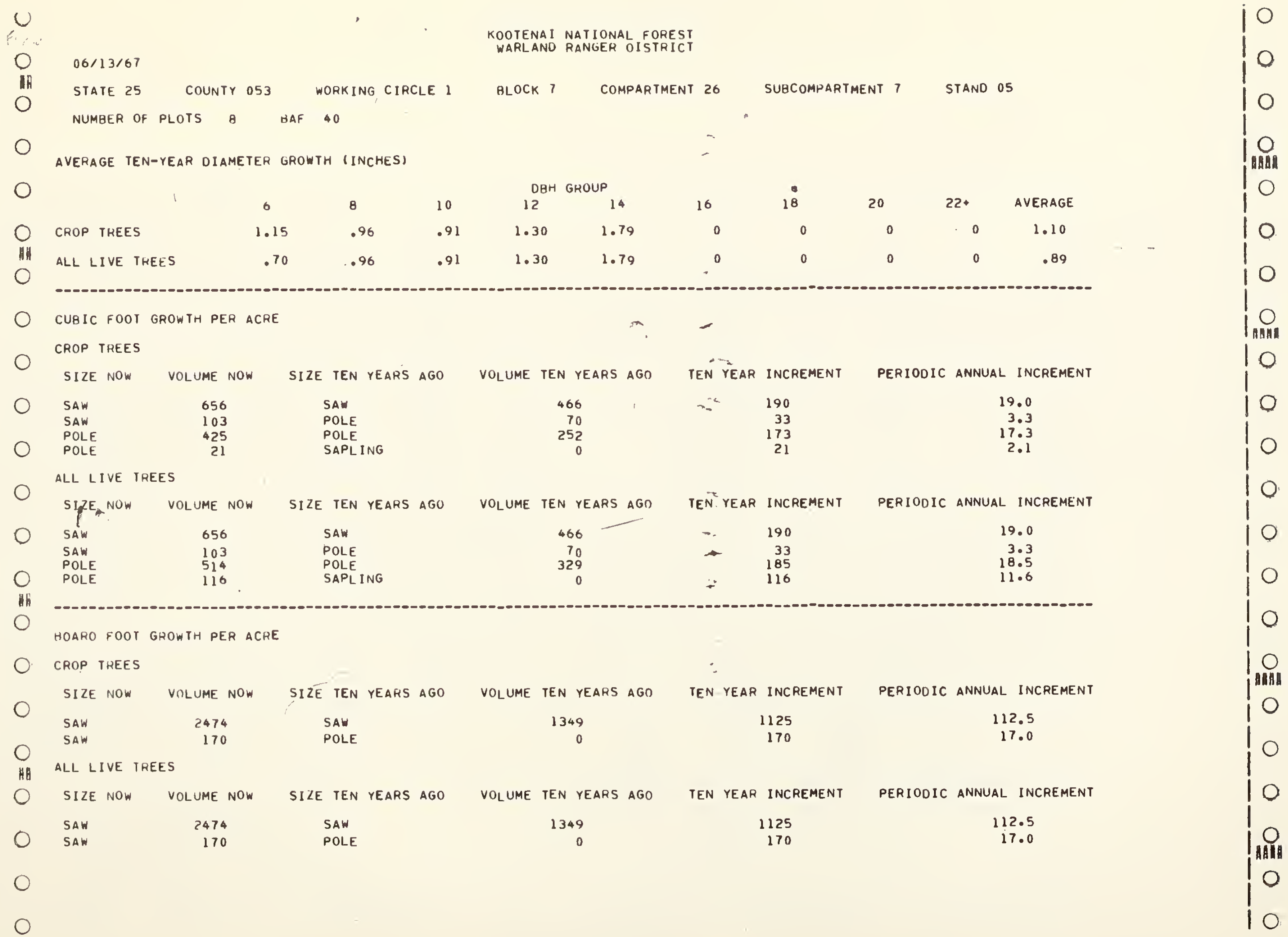

Figure 9.—Summary pointing up size and vigor of merchantable trees.



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                                              KOOTENAI NATIONAL FOREST
                                               WARLAND RANGER OISTRICT
06/13/67

STATE 25     COUNTY 053     WORKING CIRCLE 1     BLOCK 7     COMPARTMENT 26     SUBCOMPARTMENT 7     STAND 05

NUMBER OF PLOTS   8     BAF  40

AVERAGE TEN-YEAR DIAMETER GROWTH (INCHES)

                                                          DBH GROUP
                        6         8         10        12        14        16        18        20        22+      AVERAGE

CROP TREES            1.15       .96       .91      1.30      1.79        0         0         0         0        1.10

ALL LIVE TREES         .70       .96       .91      1.30      1.79        0         0         0         0         .89
-------------------------------------------------------------------------------------------------------------------------

CUBIC FOOT GROWTH PER ACRE

CROP TREES

 SIZE NOW   VOLUME NOW   SIZE TEN YEARS AGO   VOLUME TEN YEARS AGO   TEN YEAR INCREMENT   PERIODIC ANNUAL INCREMENT

 SAW           656          SAW                        466                   190                          19.0
 SAW           103          POLE                        70                    33                           3.3
 POLE          425          POLE                       252                   173                          17.3
 POLE           21          SAPLING                      0                    21                           2.1

ALL LIVE TREES

 SIZE NOW   VOLUME NOW   SIZE TEN YEARS AGO   VOLUME TEN YEARS AGO   TEN YEAR INCREMENT   PERIODIC ANNUAL INCREMENT

 SAW           656          SAW                        466                   190                          19.0
 SAW           103          POLE                        70                    33                           3.3
 POLE          514          POLE                       329                   185                          18.5
 POLE          116          SAPLING                      0                   116                          11.6
-------------------------------------------------------------------------------------------------------------------------

HOARO FOOT GROWTH PER ACRE

CROP TREES

 SIZE NOW   VOLUME NOW   SIZE TEN YEARS AGO   VOLUME TEN YEARS AGO   TEN YEAR INCREMENT   PERIODIC ANNUAL INCREMENT

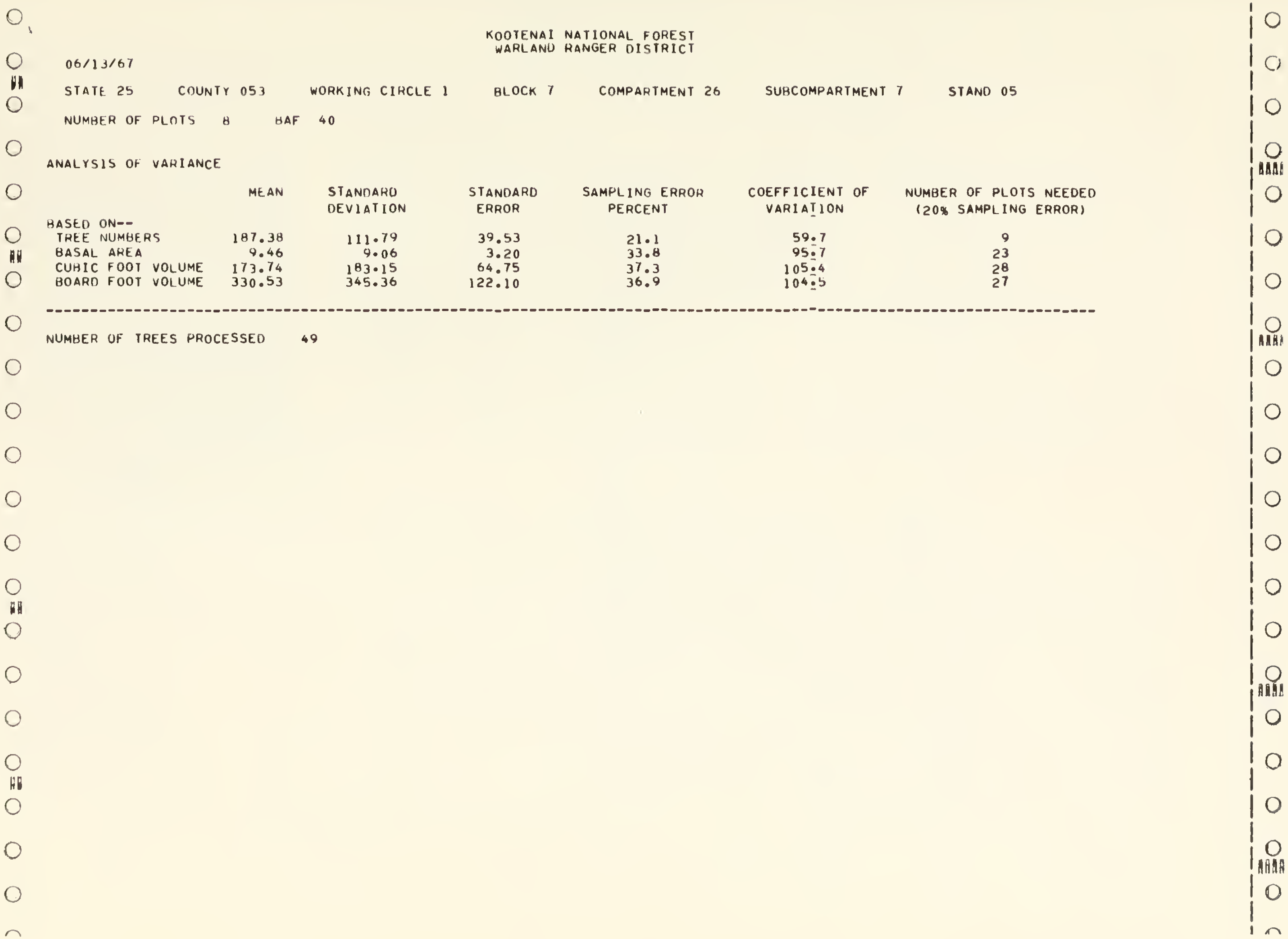
 SAW          2474          SAW                       1349                  1125                         112.5
 SAW           170          POLE                         0                   170                          17.0

ALL LIVE TREES

 SIZE NOW   VOLUME NOW   SIZE TEN YEARS AGO   VOLUME TEN YEARS AGO   TEN YEAR INCREMENT   PERIODIC ANNUAL INCREMENT

 SAW          2474          SAW                       1349                  1125                         112.5
 SAW           170          POLE                         0                   170                          17.0
```

Figure 10. — Summary of growth information collected on the stand.



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                                          KOOTENAI NATIONAL FOREST
                                           WARLAND RANGER DISTRICT
 06/13/67

 STATE 25     COUNTY 053     WORKING CIRCLE 1     BLOCK 7     COMPARTMENT 26     SUBCOMPARTMENT 7     STATE 05

 NUMBER OF PLOTS   8     BAF  40


ANALYSIS OF VARIANCE

                           MEAN      STANDARD       STANDARD     SAMPLING ERROR     COEFFICIENT OF     NUMBER OF PLOTS NEEDED
                                     DEVIATION       ERROR          PERCENT           VARIATION        (20% SAMPLING ERROR)
BASED ON--
 TREE NUMBERS            187.38       111.79         39.53           21.1               59.7                  9
 BASAL AREA                9.46         9.06          3.20           33.8               95.7                 23
 CUBIC FOOT VOLUME       173.74       183.15         64.75           37.3              105.4                 28
 BOARD FOOT VOLUME       330.53       345.36        122.10           36.9              104.5                 27

-------------------------------------------------------------------------------------------------------------------------------

NUMBER OF TREES PROCESSED     49
```
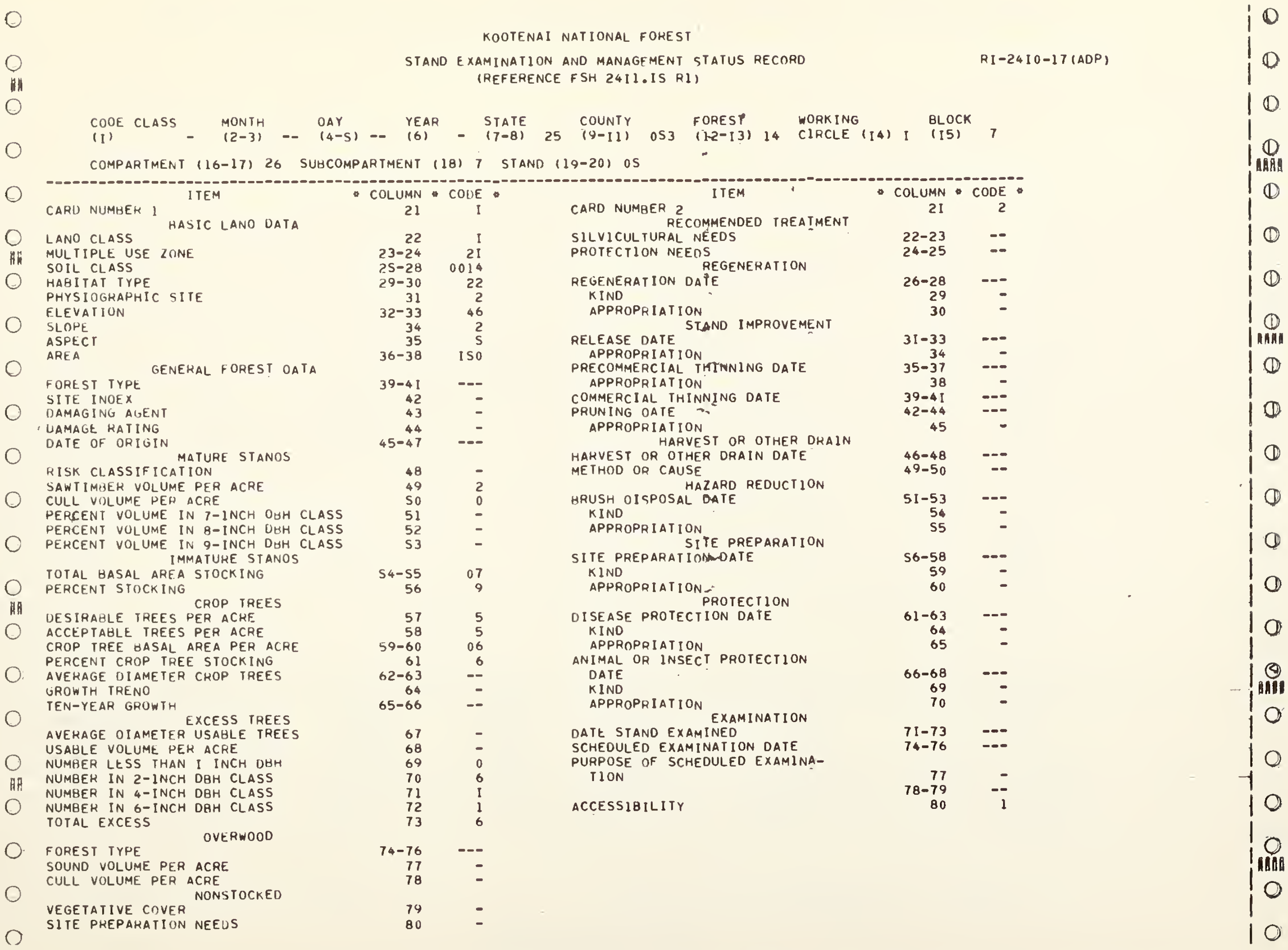

Figure 11. — Summary of statistics required to properly interpret the data collected on the stand.



KOOTENAI NATIONAL FOREST

STAND EXAMINATION AND MANAGEMENT STATUS RECORD — RI-2410-17(ADP)
(REFERENCE FSH 2411.15 R1)

CODE CLASS (1) - MONTH (2-3) -- DAY (4-5) -- YEAR (6) - STATE (7-8) 25 COUNTY (9-11) 053 FOREST (12-13) 14 WORKING CIRCLE (14) 1 BLOCK (15) 7

COMPARTMENT (16-17) 26 SUBCOMPARTMENT (18) 7 STAND (19-20) 05

| ITEM | COLUMN | CODE |
|---|---|---|
| CARD NUMBER 1 | 21 | 1 |
| BASIC LAND DATA | | |
| LAND CLASS | 22 | 1 |
| MULTIPLE USE ZONE | 23-24 | 21 |
| SOIL CLASS | 25-28 | 0014 |
| HABITAT TYPE | 29-30 | 22 |
| PHYSIOGRAPHIC SITE | 31 | 2 |
| ELEVATION | 32-33 | 46 |
| SLOPE | 34 | 2 |
| ASPECT | 35 | 5 |
| AREA | 36-38 | 150 |
| GENERAL FOREST DATA | | |
| FOREST TYPE | 39-41 | --- |
| SITE INDEX | 42 | - |
| DAMAGING AGENT | 43 | - |
| DAMAGE RATING | 44 | - |
| DATE OF ORIGIN | 45-47 | --- |
| MATURE STANDS | | |
| RISK CLASSIFICATION | 48 | - |
| SAWTIMBER VOLUME PER ACRE | 49 | 2 |
| CULL VOLUME PER ACRE | 50 | 0 |
| PERCENT VOLUME IN 7-INCH DBH CLASS | 51 | - |
| PERCENT VOLUME IN 8-INCH DBH CLASS | 52 | - |
| PERCENT VOLUME IN 9-INCH DBH CLASS | 53 | - |
| IMMATURE STANDS | | |
| TOTAL BASAL AREA STOCKING | 54-55 | 07 |
| PERCENT STOCKING | 56 | 9 |
| CROP TREES | | |
| DESIRABLE TREES PER ACRE | 57 | 5 |
| ACCEPTABLE TREES PER ACRE | 58 | 5 |
| CROP TREE BASAL AREA PER ACRE | 59-60 | 06 |
| PERCENT CROP TREE STOCKING | 61 | 6 |
| AVERAGE DIAMETER CROP TREES | 62-63 | -- |
| GROWTH TREND | 64 | - |
| TEN-YEAR GROWTH | 65-66 | -- |
| EXCESS TREES | | |
| AVERAGE DIAMETER USABLE TREES | 67 | - |
| USABLE VOLUME PER ACRE | 68 | - |
| NUMBER LESS THAN 1 INCH DBH | 69 | 0 |
| NUMBER IN 2-INCH DBH CLASS | 70 | 6 |
| NUMBER IN 4-INCH DBH CLASS | 71 | 1 |
| NUMBER IN 6-INCH DBH CLASS | 72 | 1 |
| TOTAL EXCESS | 73 | 6 |
| OVERWOOD | | |
| FOREST TYPE | 74-76 | --- |
| SOUND VOLUME PER ACRE | 77 | - |
| CULL VOLUME PER ACRE | 78 | - |
| NONSTOCKED | | |
| VEGETATIVE COVER | 79 | - |
| SITE PREPARATION NEEDS | 80 | - |

| ITEM | COLUMN | CODE |
|---|---|---|
| CARD NUMBER 2 | 21 | 2 |
| RECOMMENDED TREATMENT | | |
| SILVICULTURAL NEEDS | 22-23 | -- |
| PROTECTION NEEDS | 24-25 | -- |
| REGENERATION | | |
| REGENERATION DATE | 26-28 | --- |
| KIND | 29 | - |
| APPROPRIATION | 30 | - |
| STAND IMPROVEMENT | | |
| RELEASE DATE | 31-33 | --- |
| APPROPRIATION | 34 | - |
| PRECOMMERCIAL THINNING DATE | 35-37 | --- |
| APPROPRIATION | 38 | - |
| COMMERCIAL THINNING DATE | 39-41 | --- |
| PRUNING DATE | 42-44 | --- |
| APPROPRIATION | 45 | - |
| HARVEST OR OTHER DRAIN | | |
| HARVEST OR OTHER DRAIN DATE | 46-48 | --- |
| METHOD OR CAUSE | 49-50 | -- |
| HAZARD REDUCTION | | |
| BRUSH DISPOSAL DATE | 51-53 | --- |
| KIND | 54 | - |
| APPROPRIATION | 55 | - |
| SITE PREPARATION | | |
| SITE PREPARATION DATE | 56-58 | --- |
| KIND | 59 | - |
| APPROPRIATION | 60 | - |
| PROTECTION | | |
| DISEASE PROTECTION DATE | 61-63 | --- |
| KIND | 64 | - |
| APPROPRIATION | 65 | - |
| ANIMAL OR INSECT PROTECTION | | |
| DATE | 66-68 | --- |
| KIND | 69 | - |
| APPROPRIATION | 70 | - |
| EXAMINATION | | |
| DATE STAND EXAMINED | 71-73 | --- |
| SCHEDULED EXAMINATION DATE | 74-76 | --- |
| PURPOSE OF SCHEDULED EXAMINATION | 77 | - |
| | 78-79 | -- |
| ACCESSIBILITY | 80 | 1 |

Figure 12. — Outline of information items carried in the resource information system. Specific information for the stand used as an illustration has been added where applicable.

# APPENDIX B

Before Forest managers can effectively control costs they must have cost information that can be related to specific projects and situations. Also they must be able to compare actual costs with planned costs. The cost and project work plan summary illustrated in figure 13 has proved to be a useful management tool because it permits managers to make these comparisons readily. Often it is desirable to consider costs in relation to the stand or area treated; this is easily done, since the compartment, subcompartment, and stand numbers shown are the same as those used to identify the stand or area in the resource records, which are also in machine storage and can be quickly retrieved.

It is a rather simple computer task to produce the cost and work plan summary if all approved project work plans are given an identification number and placed in machine storage, and if the project work plan number is included on all expense documents. This summary of the work program, which is compiled at the beginning and end of each fiscal year and periodically during the year, shows the following information for each project:

1. Status (approved, contracted, completed).
2. Type of work (slashing, thinning, prescribed burning, etc.)
3. Size of area treated (number of acres).
4. Identification of the stand treated (compartment, subcompartment, and stand numbers.
5. Estimated cost of the job (provision is made for correcting the cost estimate once).
6. Accrued charges to date by appropriation and function.
7. Number of meals, vehicle miles, and machine hours charged.
8. Unit cost estimated and the actual unit cost that is computed when the project status is changed to "completed."
9. Any irregularities in fiscal coding. An editing program has been built into the program that makes these summaries. The statement "unplanned appropriation and/or function" indicates that the appropriation or function appearing on an expense document is incompatible with the planned financing and/or fiscal policy.

The project work plan summary lays out the entire work program by Ranger Districts and Forests so that the managers can quickly and easily

1. check program progress,
2. compare planned and actual costs and pinpoint areas where either work planning was inadequate or progress went sour, and
3. detect any fiscal accounting errors that may have been made.

The type of summary illustrated is only one of many that are being prepared or could be prepared. Because all the data required in decision making and reporting are included in the basic documents placed in machine storage, it is a rather simple machine process to prepare listings and summaries of accomplishments by political or National Forest units, kinds of work, class of funds, or time period. In addition, special resource record summaries are used extensively in program planning. It is a simple process, for example, to list out at any time, from all the areas on which site preparation work is completed, those that are in need of planting or for which regeneration survey must be carried out. Stands in need of thinning can be quickly sorted and listed by site and stand characteristics.

The utility of any information system is, however, limited by the utility and completeness of the information fed into it and by the flexibility built into it to allow different kinds of records to be related one to another; for example, resource records to cost and work planning records. By Northern Region procedure, an examination (stage two survey) must be made for every stand brought under management, and a stand record must be established. Before any management action is taken, a plan of action must be prepared and approved. As work progresses and costs are incurred, these must be identified by project work plan number so that they can be charged against the project in accounting. When a project is completed, the work plan status is changed and the resource record is updated to show the new condition created in the stand or area treated. However, before the resource record is updated, a temporary computer record is made of the stand situation treated, so that this data will be available for use in cost analysis.

```
                                                     PROJECT  WORK  PLAN  SUMMARY
                                                                                                   05/17/67
FOREST  KOOTENAI                          DISTRICT/UNIT  YAAK                                                               PAGE   3
                                                                                                                      0000FIRST-EST.
PWP  STATUS        TYPE OF WORK           AREA COMP SUB  STANDS    SUB   STANOS     APP/FUN  APP/FUN  APP/FUN  EST/TOTAL    MONEY  ACRES
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

008  APPROV  MACH. PILE AND SCARIFY        61   49   1  06 00 00     00 00 00    724/033  735/031  000/000    2,815      2,815    61
                                                                  YEAR-TO-OATE           APP/FUN        EXPEND.  MEALS   MILES    HOURS
                                                                   INFORMATION

                                                                                         724/033          16.30                      4.0
                                                                                         735/031          16.30                      4.0

                                                           FIRST/EST FINAL/EST   EST/UNIT  UNIT COST   ACCRUEO

                                           TOTALS           2,815.00 2,815.00     46.14                 32.60                        8.0*


009  APPROV  MACH. PILE AND SCARIFY       118   50   3  01 02 00     04 06 07    724/033  735/031  000/000    5,395      5,395   118
                                                                  YEAR-TO-OATE           APP/FUN        EXPEND.  MEALS   MILES    HOURS
                                                                   INFORMATION

                                                                                         724/033       3,362.14           71.0      20.0
                                                                                         735/031       3,389.84          170.0      20.0

                                                           FIRST/FST FINAL/EST   EST/UNIT  UNIT COST   ACCRUEO

                                           TOTALS           5,395.00 5,395.00     45.72              6,751.98           241.0      40.0*


010  APPROV  PRESCRIBED BURNING           120   01   2  03 04 05     06 11 00    724/033  735/031  000/000    2,942      2,942   120
                                                                  YEAR-TO-OATE           APP/FUN        EXPEND.  MEALS   MILES    HOURS
                                                                   INFORMATION

                                                                                         724/033         274.45     5     40.0      64.0
                                                                                         735/031         432.22     3    104.0      58.0

                                                           FIRST/EST FINAL/EST   EST/UNIT  UNIT COST   ACCRUED

                                           TOTALS           2,942.00 2,942.00     24.51                706.67     8    144.0     122.0*


011  APPROV  PRESCRIBED BURNING            45   05   2  11 13 15     16 00 00    724/033  735/031  000/000    1,051      1,051    45
                                                                  YEAR-TO-DATE           APP/FUN        EXPEND.  MEALS   MILES    HOURS
                                                                   INFORMATION
```

Figure 13. — Examples of project work plan summary. (Second example on next page.)

```
                                                  PROJECT  WORK  PLAN  SUMMARY
                                                                                                05/17/67
FOREST  KOOTENAI                          DISTRICT/UNIT  REXFORD                                                        PAGE   6
                                                                                                                    0000FIRST-EST.
PWP  STATUS        TYPE OF WORK            AREA COMP SUB  STANDS   SUB   STANDS    APP/FUN  APP/FUN  APP/FUN  EST/TOTAL   MONEY  ACRES
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

023  COMPLT  COMB. SLASH/PRESC. BURN        20  08   6  09 00 00     00 00 00   735/031  000/000  000/000     600       600      20
                                                                   YEAR-TO-DATE         APP/FUN       EXPEND.  MEALS    MILES    HOURS
                                                                    INFORMATION

                 UNPLANNED APPROPRIATION AND/OR FUNCTION ......                          724/033        343.98
                 UNPLANNED APPROPRIATION AND/OR FUNCTION ......                          724/034         37.50
                                                                                         735/031      1,870.53          502.3    344.5

                                                         FIRST/EST FINAL/EST   EST/UNIT  UNIT COST    ACCRUED

                                             TOTALS          600.00    600.00     30.00     112.60    2,252.01          502.3    344.5*


024  COMPLT  PRESCRIBED BURNING             24  22   6  03 00 00     00 00 00   735/031  724/033  000/000     480       480      24
                                                                   YEAR-TO-DATE         APP/FUN       EXPEND.  MEALS    MILES    HOURS
                                                                    INFORMATION

                                                                                         724/033        256.78                    60.0
                                                                                         735/031        218.17                    48.0

                                                         FIRST/EST FINAL/EST   EST/UNIT  UNIT COST    ACCRUED

                                             TOTALS          480.00    480.00     20.00      19.78      474.95                   108.0*


025  COMPLT  PRESCRIBED BURNING            117  18   2  03 04 00     04 00 00   735/031  724/033  000/000   2,340     2,340     117
                                                                   YEAR-TO-DATE         APP/FUN       EXPEND.  MEALS    MILES    HOURS
                                                                    INFORMATION

                                                                                         724/033      1,087.06          299.0    206.0
                                                                                         735/031      1,540.32          582.0    322.0

                                                         FIRST/EST FINAL/EST   EST/UNIT  UNIT COST    ACCRUED

                                             TOTALS        2,340.00  2,340.00     20.00      22.45    2,627.38          881.0    528.0*


026  COMPLT  PRESCRIBED BURNING             30  02   5  01 00 00     00 00 00   735/031  000/000  000/000     320       320      40
                                                                   YEAR-TO-DATE         APP/FUN       EXPEND.  MEALS    MILES    HOURS
                                                                    INFORMATION
```

# APPENDIX C

Statistical data for variables used in illustrations, including means, standard deviations, and variable ranges where appropriate:

| *Variable* | *Mean* | *Standard deviation* | *Range* |
|---|---|---|---|
| Area in acres | 58.3 | 54.9 | 4-275 |
| Number of trees planted per acre | 415 | 130 | 93-600 |
| Total trees planted | 24,085 | 22,384 | 2,000-89,100 |
| Area$^2$ | 6,354 | 12,770 | -- |
| Area$^2$ × trees per acre | 2,534,082 | 4,448,200 | -- |
| Area$^2$ × total trees planted | 378,521,290 | 1,061,133,900 | -- |

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Headquarters for the Intermountain Forest and Range Experiment Station are in Ogden, Utah. Project headquarters are also at:

- Boise, Idaho
- Bozeman, Montana (in cooperation with Montana State University)
- Logan, Utah (in cooperation with Utah State University)
- Missoula, Montana (in cooperation with University of Montana)
- Moscow, Idaho (in cooperation with the University of Idaho)
- Provo, Utah (in cooperation with Brigham Young University)

*"The Forest Service of the U.S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives — as directed by Congress — to provide increasingly greater service to a growing Nation."*